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The Institute of Vitreous Enamellers
The National Ironfounding Employers' Federation
The Welsh Engineers' and Founders' Association
and
The Foundry Trades' Equipment and Supplies Association

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Re-Christening Cast Iron

The question of the name of cast iron has cropped up again. It is suggested, in view of the associations in the mind of the ordinary engineer with the old type of cast iron, that it would be better to find a new name for the modern types of high-quality material. Part of the suggestion is that conservative ideas on what cast iron can do prevent engineers from seriously trying the new products. The problem is difficult to decide, and we are familiar with the proverb about giving a dog a bad name. The words "cast iron" to-day, like the word "steel," cover a wide range of products which vary considerably among themselves, some good, others poor; some expensive, others cheap. Difficulties always arise about the general designation of a range of products, and indeed, part of the trouble about cast iron would go if it were realised that it covers a variety of products suited to particular requirements. The pros and cons may be stated as follows. Against any change it may be said that the phrase cast iron has the advantage of tradition, and that it would be easier, in these days of publicity, to change ideas about cast iron (as they *are* being changed) than to change the label. People's ideas about cast iron, so to speak, are too cast iron, and were they less so it would be understood that there are cast irons, and that in a range there are different types. For the change it may be argued that the modern cast irons are so markedly improved over their predecessors that they form new materials, and justify a new title. But anyone who has tried to popularise a trade name knows how difficult it is to get a new name accepted generally, and the main difficulty of deciding on a name remains. Even "cast ferrous alloys" may be made badly or unsuitably. On the whole, we favour the retention of cast iron, making the idea of it respectable and representative among users. This situation, however, is not improved if makers or users of the better cast irons refer to them as steels, a procedure welcome neither to steelmakers nor to founders. A machinable ferrous material containing free graphite, however small the quantity, is metallurgically a cast iron. It is true that it approaches the border line of the steels when the graphite content is small, as in certain types of crank shaft, but when we remember that the change from steel to cast iron was made for definite reasons which engineers can appreciate, it is doubly desirable that the proper description be used.

Diminished Tolerances

A serious indictment is made against the great national buying authorities in a Report submitted by the Sub-Committee of the Technical Committee on Malleable Cast Iron to the Annual Conference of the Institute of British Foundrymen. This indictment is directed against loose phraseology and general indefiniteness, which in itself would be useless were it not for the fact that the Sub-Committee has now produced sufficient reliable data for the creation of provisional clauses in a considerable number of specifications. The report emphasises that the achievement of dimensional accuracy is a function of quantity and the method of moulding used. It has well stressed the complexity of the problem and in a measure indicates that a special specification might be evolved dealing with this phase to which other specifications would make reference, in place of working out a specially appropriate clause. Thus clauses relating to dimensional accuracy might well in the future read: to be in accordance with B.S. specification No. x. Such a method of specification could usefully take care of quantity and method of production. Experience would soon show whether industrial purposes would best be served by issuing one specification to take care of all types of castings or, say, four specifications to deal with the specific cases of grey iron, steel, malleable and non-ferrous castings.

What should be borne uppermost in mind is the avoidance of disputes resulting from such looseness of expression as now exists. Typical amongst these are "close agreement"; "accurately moulded"; "reasonable limits." Next in importance is a revision of the tolerances, where they are definitely specified to conform with the natural properties of metals and alloys as related to the phenomena of solidification and thermal history changes. Much of this has been determined by research, and existing gaps could quickly be filled by co-operative research. The present position is obviously unsatisfactory and the Institute of British Foundrymen deserves the thanks of the whole of the engineering profession for directing attention to what is a fundamental factor in the standardisation of foundry products.

International Acetylene Congress

The twelfth International Congress of Acetylene, Oxy-Acetylene Welding and Allied Industries is being held in London this week. More than 600 delegates, representative of 15 nations, are taking part, and some sixty Papers are being presented for discussion at the technical sessions which are being held in Caxton Hall, Westminster, throughout the week.

The inaugural ceremony took place at the Guildhall on Monday morning, Dr. J. Donald Pollock, O.B.E. (President), presiding.

The following telegram, addressed by the private secretary of His Majesty the King to the President, in reply to a message of loyal greeting from the delegates, was read:—

"I am commanded by the King to convey through you to all present at the Twelfth International Congress of Acetylene, Oxy-Acetylene Welding and Allied Industries, His Majesty's sincere appreciation of their loyal assurances. His Majesty, who had been pleased as Prince of Wales to give his patronage to the forthcoming Congress, takes this opportunity of wishing you all success in your deliberations."

THE PRESIDENT, in his opening address, remarked on the beauty of the building in which they were gathered, and reminded them that this and similar structures were the outcome of scientific principles carried out by skilled technical workers with fine materials. But they implied inspiration and the higher qualities of an immaterial, or rather a spiritual nature.

LORD ALNESS, in an address of welcome to the members, expressed regret at the absence of Italian representatives for the first time since these international congresses were held. The present Congress, he said, had four unique features. It was the first time it had been honoured by Royal patronage; it was the first acetylene congress to be held in London for 28 years; it coincided with the centenary of the discovery—made in England—of acetylene gas, and it marked the 50th anniversary of the first commercial production—also in England—of oxygen.

MR. A. GANDILLON (President of the Swiss Acetylene Association and of the Commission Permanente Internationale) also addressed the delegates.

The prizes awarded for Papers submitted to the Congress were presented by Lord Alness, as follow:—

XIIth Congress Gold Medal with Vellum Certificate.—Mr. R. Meslier (France).

XIIth Congress Silver Medals with Vellum Certificates.—Messrs. J. Brillie, A. Leroy and A. Roux (France); and Messrs. F. Golling and P. Tulacz (Poland).

British Acetylene Association Gold Medal with 25 guineas (awarded for the best Paper submitted in English by persons of British nationality).—Mr. C. G. Bainbridge and Mr. R. E. Dore.

British Acetylene Association Silver Medal with 10 guineas.—Mr. W. H. G. Hignett.

Government Reception

On Monday evening a Government Reception was held at Lancaster House, St. James's, in honour of the Congress, the guests being received by the Minister of Health (the Rt. Hon. Sir Kingsley Wood) and Lady Kingsley Wood. The band of the Grenadier Guards played during the evening.

The Congress banquet was held on Tuesday night at Grosvenor House, Park Lane, Dr. J. Donald Pollock presiding.

Yesterday afternoon one group of delegates visited the works of the British Oxygen Company, Limited, at Cricklewood and at Edmonton, while a second party went to the works of Electrolux, Limited, at Luton.

This evening (Thursday) a river trip on the Thames has been arranged, the members travelling by train to Marlow, whence they will go by boat to Windsor, returning to town by train.

At the invitation of the British Oxygen Company, Limited, the members will have the opportunity of witnessing the Aldershot Tattoo to-morrow (Friday) night.

The closing session of the Congress will be held at Caxton Hall on Saturday morning at 11 a.m.

Lancashire Foundrymen Visit Dagenham

Nearly eighty members of the Lancashire Branch of the Institute of British Foundrymen last Friday were shown over the foundry department of the Ford Motor Company, Limited, at Dagenham. Mr. J. Hogg, the Branch-President, headed the party, and amongst others participating were Mr. Grundy, Mr. Pell, Mr. Cook, Mr. Miles, Mr. Key and Mr. Flower, whilst arrangements were in the hands of the honorary secretary, Mr. J. E. Cooke. On arrival at the Club House of the Ford Sports Club, the party was received by Mr. Fox and Mr. Meldrum, the former making a short speech of welcome and at the same time indicating the arrangements for conducting the party round the works. The coaches were used to cover the mile between the Club House and the foundry, and guides pointed out the items of interest. Most of the time available was spent in the foundries, the manufacture of the cast iron crank shafts being especially appreciated.

After tea, MR. HOGG thanked the hosts for the excellent facilities they had placed at the disposal of the visitors. He complimented them on their organisation, and said he had not failed to notice the high temperature of the metal used, and the fine finish of the castings made.

MR. GRUNDY, in supporting, said how much the visitors had appreciated being allowed to spend so much time in the actual foundry. He really felt they had been accorded a special privilege.

MR. FOX, in acknowledging the thanks expressed, said that obviously the plant was too large to be thoroughly inspected in one short visit, but on behalf of the management he extended an invitation to each one of them to re-visit the works as individuals. Moreover, if they wanted any information about the works, or indeed about any other problem connected with foundry practice, they had only to write to Dagenham and they would receive an intelligent answer from their technical specialists within twenty-four hours.

MR. MELDRUM, in a short address, said whilst his firm belonged to no national research association, he felt that their own international research organisation, spread as it was all over the world, could, because of close co-operation, provide technical data of a very high degree of accuracy in very considerable quantities.

The party returned to Manchester at about 6.30 in the evening after spending a particularly strenuous day.

The Scottish Conference

The Annual Conference of the Institute of British Foundrymen, which is being held in Glasgow and Edinburgh this week, will be fully reported in the "Foundry Trade Journal" next Thursday.

The New East Anglian Section

Early in the present year, Mr. L. J. Tibbenham, of Suffolk Iron Foundry (1920), Limited, suggested the formation of a Section of the London Branch of the Institute of British Foundrymen to operate in the Eastern Counties for the benefit of those who found difficulty in travelling to London to attend meetings. A preliminary meeting—reported at length in our issue of April 2 last—was held at Ipswich on March 24, the chair being taken by Mr. F. O. Blackwell, President of the London Branch, supported by Mr. A. S. Stokes, of Ransomes & Rapier, Limited, Mr. S. C. E. Lloyd, of Stewarts and Lloyds, Limited, and Mr. T. Makemson, the General Secretary of the Institute.

On that occasion Dr. A. B. Everest delivered a Paper entitled "The Development of Cast Iron in the Past 25 Years." An attendance of over 100 was recorded at this meeting, and the response was such as amply to justify the formation of a local Section to be known as the East Anglian Section of the London Branch of the Institute of British Foundrymen.

At a subsequent meeting held on May 22, Mr. V. Delport, Senior Vice-President of the London Branch presided, supported by the London Branch-Secretary, Mr. H. W. Lockwood. The following officers of the new Section were then elected:—

President.—Mr. L. J. Tibbenham.
Senior Vice-President.—Col. C. Portway.
Junior Vice-President.—Mr. H. H. Shepherd.
Council.—Mr. C. H. Kain, Mr. W. B. Lake, J.P., Mr. G. Detlefsen, Mr. G. Hall, Mr. R. Dunnett and Mr. A. Hammond.
Hon. Secretary.—Mr. J. L. Francis.

Most of the principal firms in East Anglia have given wholehearted support to this new development, and about thirty new members of the Institute have been enrolled as a direct result. The Section Council is taking immediate steps to arrange works visits and not less than six meetings a year will be arranged at the principal centres in the Eastern Counties.

Book Review

The Outline of Steel and Iron. By Archibald Allison. Published by H. F. & G. Witherby, Limited, 326, High Holborn, London, W.C.1. Price 6s. net.

The author has set out to present an outline of the whole of the iron and steel manufactures as they are at present, and he has certainly succeeded in achieving his aim.

The origins of iron and steel are clearly dealt with and the remainder of the book is devoted to the various types of iron and steel manufactures presented in an entirely non-technical manner. The fact that the author uses the word "rusting" instead of oxidation or corrosion is an indication of the simple language which is used throughout. It should prove interesting to the metallurgist if only for the historical aspect, but its main appeal will be to the very large number of readers whose activities in life, while not demanding a highly technical and scientific knowledge, call for a true understanding of the basic principles of the manufacture of iron and steel and the uses to which these materials are put.

The chapter on "Cast Iron" will be read with interest by all those connected with the foundry industry, but we cannot agree with the writer's assertion that "for some obscure reason iron castings have never commanded an economic price, and a profit is only possible by studying the most minute economies in production."

The work is amply illustrated by ancient engravings and modern photographs.

H. W. L.

The Fracture of Pig-Iron and Cast Iron*

By A. L. NORBURY, D.Sc., and E. MORGAN, M.Sc. (The British Cast Iron Research Association)

Introduction

The fracture of pig-iron is in some ways less important in the foundry nowadays than it used to be, when it was the only guide to the fracture to expect in castings made from that pig-iron. Nowadays chemical analysis of the iron is used in many foundries to control the product, and in some cases the analysis is controlled remarkably closely, for example to within ± 0.1 per cent. of total carbon, silicon, manganese and phosphorus. In other ways, however, the fracture of pig-iron and of cast iron—which is the same material from the present point of view—is taking on a new importance, since chemical analysis of itself does not give a complete guide to the properties of cast iron. It is possible for two pig-irons or two castings of the same general analysis to have different fractures and widely-different mechanical and other properties. The investigation and control of such differences is consequently of considerable importance.

In order to recognise differences in pig-irons not revealed by general chemical analysis, it is first of all necessary to understand how variations in general chemical analysis affect the fracture. Consequently in the present Paper, after describing the various fractures of pig-iron, the effect of composition, and particularly carbon and silicon content, on the fracture, is first dealt with. Following this illustrations are given of differences in fracture which are not revealed by the general chemical analysis, such differences being produced by the presence in the metal of finely divided non-metallic inclusions, particularly those containing titanium.

Numbering of Pig-Iron Fractures

The coarseness of the fracture of a pig-iron is conventionally indicated by a number or by a name such as "half-bar," "forge," "cylinder," etc. The coarsest fracture is known as a No. 1, and the progressively finer ones as Nos. 2, 3, 4, etc. The openness of the fracture depends on the size of the graphite flakes, which are as large as about ⅛ in. across in the middle of a No. 1 fracture and up to about $\frac{1}{16}$ in. in the No. 2 fracture. Both these fractures are coarser in the middle than round the outside. In the No. 3 fracture, however, this is not the case. A remarkable difference occurs. The fracture is fine in the lower part of the pig and coarse in the upper part, somewhat as shown in Fig. 1B.† The differences in the coarseness of this fracture are due to local differences in total-carbon content—as shown in Fig. 1—the carbon having floated up during solidification. In the fine part the carbon content is not above the eutectic composition and in the coarse part it is above it, and coarsens the fracture as discussed in detail later. The fine area in this type of fracture can vary in extent from a small patch in the middle of the lower half of the fracture, to a large area extending higher up than shown in Fig. 1B, according to the composition of the pig and consequent extent of the area containing less carbon than the eutectic value. The rim of such a fracture may contain more carbon than the eutectic and be coarse, since it solidifies more rapidly, and this prevents carbon floating up out of it and lowering its composition to below the eutectic.

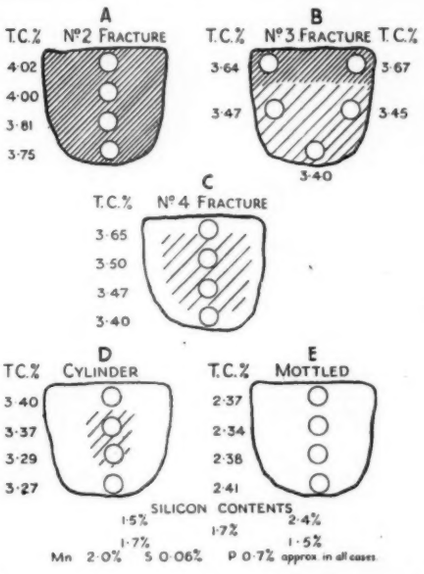

FIG. 1.—FLOTATION OF GRAPHITE IN PIG-IRONS OF DIFFERENT FRACTURE.

The next fracture is a No. 4 or forge. This fracture is below the eutectic composition throughout, and is coarser in the middle than at the outside, due to the normal rate of cooling effect. Progressively finer fractures are of similar type, and are known as No. 5, No. 6, cylinder, etc., and finally there are, of course, mottled, spotted white and white fractures.

In passing, it may be noted that the numbering given by different furnaces to given fractures varies considerably, since a furnace making close fractured irons only occasionally makes very open irons, and *vice versa*. The result is that a different range of numbering, and sometimes a different number for the same type of fracture, is adopted. It would be an advantage if a standard system of numbering could be devised which could be adopted by all furnaces.

Effect of Carbon and Silicon on Fracture

The two chief elements of composition which affect the fracture are the carbon and silicon contents. The higher the carbon in a given composition, the coarser the graphite flakes and the more open the fracture. Carbon is, however, not the only element which affects the fracture; silicon has an almost equally important effect. The interdependent effect of carbon and silicon on the fracture is illustrated in Fig. 2, which shows that the fracture of pig-iron made in a given furnace depends essentially on the carbon and silicon contents. Phosphorus has a very similar effect to silicon in reducing the solubility of carbon and sulphur, if not neutralised by manganese, has a chilling effect, but the chief elements of composition which affect the fracture are the carbon content and the silicon content. This was pointed out by Siegle* in 1922. This is shown in Fig. 2, where No. 1 and No. 4 fracture irons, all made in the same furnace, are plotted against total carbon and silicon. It will be seen that a No. 1 fracture iron contains about 4 per cent. total carbon when 2 per cent. silicon is present, but only 3½ per cent. total carbon with 4 per cent. silicon. That is to say, silicon in the iron lowers the total-carbon content necessary to give a certain fracture. When about 10 per cent. silicon is present—as in ferro-silicon—the blast-furnace product which has a No. 1 fracture contains only about 2 per cent. carbon.

The reason it is possible to obtain a No. 1 fracture with 4 per cent. carbon and 2 per cent. silicon, and with 2 per cent. carbon and 10 per cent. silicon is that both contain coarse kish-like graphite flakes, since silicon reduces the solubility of carbon in molten cast iron in the following manner: When no silicon is present, pig-iron can dissolve as much as 4.3 per cent. carbon, but no more, when it is just melted, which occurs at about 1,150 deg. C. (If the temperature is raised, more carbon can be dissolved.) This easily melted 4.3 per cent. carbon composition is known as the eutectic = easily melting composition, and its carbon content is reduced by the presence of silicon as follows: When 2 per cent. silicon is present and the metal is just melted at 1,150 deg. C., the metal can only dissolve 3.8 per cent. carbon. Similarly, when 10 per cent. silicon is present, only 1.8 per cent. carbon can be dissolved. In other words, silicon reduces the amount of carbon that pig-iron can dissolve at the eutectic temperature, *i.e.*, when it is just melted. As the temperature is raised above the eutectic temperature, more

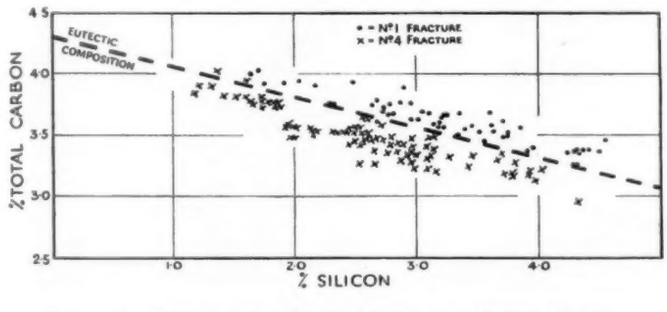

FIG. 2.—EFFECT OF TOTAL CARBON AND SILICON CONTENT ON THE FRACTURE OF PIG-IRON.

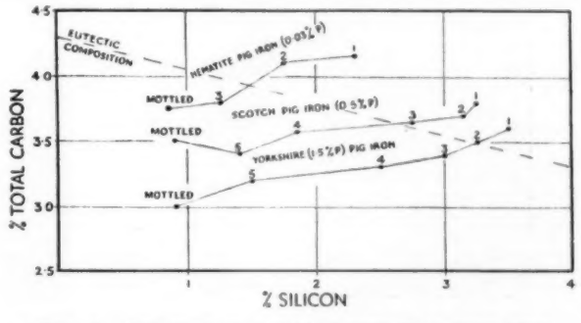

FIG. 3.—ANALYSES OF THE DIFFERENT FRACTURED PIGS PRODUCED BY THREE TYPICAL BLAST-FURNACES.

* Paper presented at the Annual Conference of the Institute of British Foundrymen in Glasgow this week.

† From Bulletin, British Cast Iron Research Association, July, 1931, p. 7. "Flotation of Graphite in Cast Iron," by A. L. Norbury, D.Sc., and C. Rowley.

* Siegle, Proceedings of the Institute of British Foundrymen, 1922, p. 54.

carbon can be dissolved; very roughly about 0.2 per cent. more carbon can be dissolved each 100 deg. C. rise in temperature. On cooling, this excess carbon, of course, becomes insoluble and forms solid graphite flakes in the molten metal. These grow to the largest size and are seen in the No. 1 fracture. They also tend to float up out of the molten metal and form kish.

Consequently, in Fig. 2 it will be seen that increasing the silicon content, by reducing the carbon content of the eutectic, reduces the carbon content at which cast iron begins to contain the kish-forming graphite which produces the No. 1 fracture. In Fig. 2, in the case of irons containing less carbon than the eutectic, it will be seen that No. 4 fractures are formed, which are not nearly so coarse as the No. 1, since they do not contain the kish-forming graphite, although they contain uniformly distributed medium-sized graphite flakes. As the carbon is further reduced below the eutectic composition, the microscope shows that the iron becomes interlaced with increasing quantities of fine fern-like crystals which are of a steel-like nature, except in so far as they are brittle in high-silicon irons, due to the silicon dissolved in them. Their effect on the fracture is to make it finer, since they reduce the amount of eutectic graphite present and restrict the growth of graphite flakes by their interlacing formation.

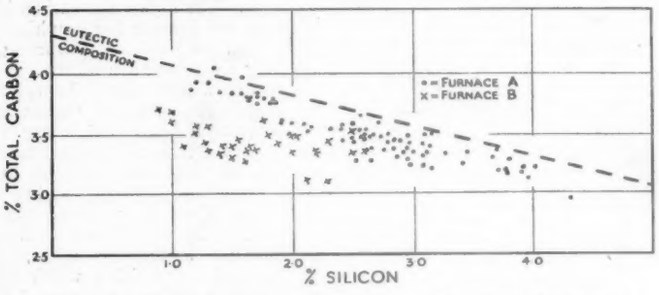

FIG. 4.—DIFFERING ANALYSES OF NO. 4. FRACTURE PIG-IRONS PRODUCED BY TWO DIFFERENT BLAST-FURNACES.

Effect of Blast-Furnace Operation on Fracture

The production of open or close fractured pig-iron depends on the burden and operating conditions in the blast-furnace and Fig. 3 gives a general idea of the average analyses of the various fractured irons produced by three typical furnaces. It will be seen in Fig. 3, first that both carbon and silicon increase as the fracture becomes more open, and secondly that the silicon content of a given fracture is consistently lower in the case of the hematite irons than it is in the case of the Yorkshire irons, and at the same time the carbon content is also lower in the latter, since the higher silicon and phosphorus contents lower the carbon content, as shown in Fig. 2.

The good qualities associated with the name cold-blast iron are, it is thought, now considered as being due to the irons being relatively low in carbon and consequently stronger, their production resulting from lower furnace temperatures, which result in less carbon being picked up.

Differences in Pig-Irons and Cast Irons Not Revealed by Ordinary Chemical Analysis

Up to the present the effect of straightforward chemical analysis on fracture has been considered, but this by itself, as stated at the outset, does not completely determine the fracture of pig-iron. This has long been observed and the something else which affects the fracture has been variously termed the "inherent property," "heredity," etc. An illustration of this type of variation in pig-iron is shown in Fig. 4, where it will be seen that the No. 4 fractures made by one furnace have not the same carbon content in an otherwise similar analysis as those made by another furnace, and that for a given silicon content the No. 4 iron from furnace B would tend to be stronger than one from furnace A, since its carbon content is lower.

In the past, the superior qualities of one pig-iron over another were probably in many cases largely accounted for by a lower carbon-content or some other analytical difference which was not fully realised. Nevertheless, at the present time, with analytical and test-bar control becoming more and more exact, it is becoming firmly established that differences do exist between different brands of pig-iron which are not revealed by ordinary chemical analysis and which may be reproduced in castings made from them. One of the first investigators of this type of variation was F. J. Cook* in 1908, who drew attention to differences in strength and phosphide network structure of grey irons of the same chemical analysis. That grey cast iron can vary in this manner is now well known and illustrations are given in Figs. 5 and 6 and Table I, where the differences in the mechanical properties of irons A and B of the same chemical analysis, are due to differences in the size of the graphite flakes. The more uniform graphite structure in iron A, giving a stronger iron in this low carbon composition, than the mixed structure in iron B.

TABLE I.—*Cast Irons A and B of the Same Analysis and Different Mechanical Properties.* (1.2 in. *Diameter Sand-Cast Bars.*)

	A	B
Total carbon, per cent. ..	2.91	2.94
Combined carbon, per cent. ..	0.62	0.80
Silicon, per cent.	1.82	1.70
Manganese, per cent.	0.67	1.00
Sulphur, per cent.	0.03	0.03
Phosphorus, per cent.	0.03	0.03
Transverse strength (tons per sq. in., 18-in. centres) ..	23.1	39.8
Tensile strength (tons per sq. in.)	14.4	23.4
Repeated impact (no. of blows to fracture)	68	3,476
Brinell hardness (10/3,000/30)	207	241

A more extreme difference in graphite size, in two high total-carbon irons of the same analysis (cast in green sand into 3 in. diameter bars, 20 in. long) is shown in Figs. 7 and 8. The fractures of the bars are shown in Figs. 9 and 10 and their different mechanical properties in Table II.

In this composition the almost completely refined fine-graphite bar D is considerably stronger than the coarse-graphite bar C.

Refining the graphite in this manner increases

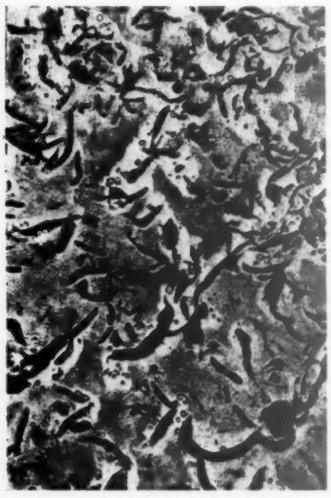

FIG. 5.—MIXED FINE AND COARSE GRAPHITE STRUCTURE OF IRON A (SEE TABLE I). × 200.

FIG. 6.—UNIFORMLY - COARSE GRAPHITE STRUCTURE OF IRON B (SEE TABLE I). × 200.

FIG. 7.—COARSE GRAPHITE STRUCTURE OF IRON C (SEE TABLE II). × 50 (UNETCHED).

* F. J. Cook, Presidential Address, Institute of British Foundrymen, 1908, p. 14, and F. J. Cook and C. Hallstone, "The Effect of Structure on the Physical Properties of Cast Iron," *Ibid.*, 1908-1909, p. 99.

the strength to the greatest extent in high total-carbon irons that are approaching the eutectic composition in carbon content. As the carbon content decreases below this, refining the graphite produces a smaller increase in strength and in the case of very low total-carbon irons it may even decrease it somewhat. It should also be noted that in low total-carbon irons* mixed

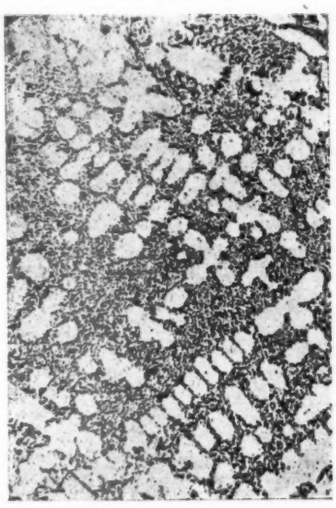

FIG. 8.—FINE GRAPHITE STRUCTURE OF IRON D (SEE TABLE II). × 50 (UNETCHED).

fine and coarse graphite structures (as shown in Fig. 5) have lower mechanical properties than uniformly coarse structures (as shown in Fig. 6).

Effect of Titanium Slag Inclusions on Graphite Size and Fracture

The change from the coarse graphite to the fine graphite structure has been produced by Piwowarsky† and others by superheating molten cast iron to above 1,500 deg. C. The authors have found that it may be produced by dissolving a small amount of ferro-titanium in molten cast iron and oxidising it by bubbling carbon-dioxide gas through the molten metal.‡ Only about 0.2 per cent. Ti is necessary, and ferro-silicon-titanium is the most easily dissolved ferro-alloy. The bar D, shown in Figs. 8 and 10, was obtained by treating in this manner a similar charge to that used for bar C, shown in Figs. 7 and 9, which was untreated. Both were crucible melted. It is thought that it is not the titanium itself, but slag inclusions formed by the titanium, which produce this effect on the way the graphite crystallises, since the titanium has to be oxidised before it has this effect. Moreover, if hydrogen is bubbled through a melt treated with titanium plus carbon dioxide, a coarse, instead of a fine graphite structure, is produced. It is also essential that the metal to be treated should be sufficiently free from other slag inclusions, and this is by no means usually the case with cupola melted metal and is being further investigated. The metal must also be below the eutectic composition for it to be fine, since kish graphite coarsens the fracture.

TABLE II.—*Cast Irons C and D of the Same Analysis and Different Mechanical Properties.* (3-*in. Diameter Sand-Cast Bars.*)

	C	D
Total carbon, per cent. ..	3.59	3.47
Combined carbon, per cent. ..	0.73	0.28
Silicon, per cent.	2.78	2.87
Manganese, per cent.	0.72	0.59
Sulphur, per cent.	0.03	0.03
Phosphorus, per cent.	0.02	0.02
Titanium, per cent.	0.07	0.28
Transverse strength (tons per sq. in. on 18-in. centres) ..	17.4	30.3
Tensile strength (tons per sq. in.) on ¾-in. bars machined from—		
(1) Half-way between centre and edge	7.5	19.5
(2) Near centre.	8.5	12.3
Brinell hardness—		
Edge	134	179
	143	179
	163	170
10/3,000/30 Centre	152	174

As a result of the above finding, a number of pig-irons were analysed for titanium, and it was found to be an almost universal constituent, but varied considerably in amount. Hematites have been found usually to contain below 0.1 per cent. titanium, Yorkshire irons about 0.15 per cent., Burn Indian pig-iron about 0.25 per cent., and certain Norwegian irons, such as Vantit and Norskalloy, as much as 0.5 per cent. or more. Burn, Vantit and Norskalloy irons are all chill cast; consequently the peculiar sooty nature of their fracture is probably often attributed to their chill casting. Moreover, the sooty fracture is not evident except in small patches unless the carbon content is below the eutectic and kish graphite is absent. When, however, these high titanium pigs are remelted in a crucible with steel to lower the carbon content, the sooty fracture is produced.

The titanium content of a pig-iron increases as the titanium content of the ores used increases and as the temperature of the blast furnace increases, since it is only reduced from the ores and dissolved in the iron at high temperatures. The slag conditions, etc., in the furnace also affect the amount dissolved. The hematite ores only contain a little titanium, the Indian ores more and the Norwegian ores still more titanium, which is in line with the titanium contents and fractures of the pig-irons produced from them. Some Irish ores also contain appreciable amounts of titanium and were used some years ago in hematite blast furnaces, and had the effect of giving the pig-iron produced quite a different fracture, which was black and sooty when kish graphite was absent.

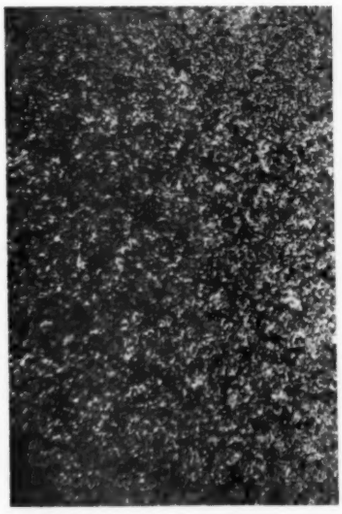

FIG. 9.—FRACTURE OF 3-IN. DIA. BAR OF IRON C (SEE TABLE II). × 1⅛TH.

Titanium slag inclusions in the metal consequently have a remarkable effect in producing the fine graphite, sooty fractures. As stated above, their effect on the fracture of pig-irons is not very evident when the composition is above the eutectic, but when it is below the eutectic a sooty black fracture is formed in the lower part of the No. 3 fracture shown in Fig. 1B, and all finer fractured irons have a uniformly sooty black fracture like that shown in Fig. 10. In most

FIG. 10.—FRACTURE OF 3-IN. DIA. BAR OF IRON D (SEE TABLE II). × 1⅛TH.

compositions Cook's network structure can also be clearly seen in the fracture and becomes increasingly marked as the phosphorus content is raised. Other types of slag inclusions produce the coarse fracture, and there appear to be all sorts of intermediate conditions, depending on the amounts of the different sorts of slag inclusions in the metal. For the production of the fine graphite structure, however, the titanium slag inclusions appear to have the predominating effect and the differences in fracture and properties ordinarily met with in the foundry which are not revealed by ordinary chemical analysis appear to be related to titanium slag inclusions in the metal more than to anything else.

Finally, it should be pointed out that on remelting there is a tendency for other slag particles to form in the metal and remove, and obliterate the effect of, the original ones, and consequently to obliterate the original type of fracture. The extent to which this occurs depends on the melting conditions, which are at the present time under investigation.

In conclusion, the authors wish to thank the Council of the British Cast Iron Research Association for permission to publish the present results, and to thank members of the Pig-iron Sub-Committee of the British Cast Iron Research Association for data and much helpful information and discussion on the subject.

* Attention was drawn to this in a Paper by the authors in the Journal of the Iron and Steel Institute, 1930 (I), pp. 367–392.
† E. Piwowarsky, Transactions of the American Foundrymen's Association, 1926, vol. 34, p. 914.
‡ British Patent 425,227 of 1935.

U.S. and the Steel Cartel

Lord Dudley, President of the British Iron and Steel Federation, who, with Sir Andrew Duncan, independent chairman of the Federation, and Mr. I. F. L. Elliott, commercial director, were passengers in the "Queen Mary" on her maiden voyage across the Atlantic, broadcast from the new liner while she was in New York Harbour.

Lord Dudley stated during his broadcast that they were taking that early opportunity of consulting with American steel interests in order that they might explain to them the details and objects of European steel organisations, to invite them to join in a pooling of resources, experience and technical skill in developing the markets of the world to common advantage.

Recommendations for Two Leaded Gunmetals*

By the Non-Ferrous Sub-Committee of the Technical Committee of the Institute of British Foundrymen

Leaded gunmetals are very largely used for a wide variety of purposes in engineering practice, and in the absence of any standard specifications for these, alloys are made by the foundry industry to comply with a very large number of different requirements of individual purchasers. The most widely known of the gunmetals is the alloy known as "Admiralty gunmetal," for which the British Standards Institution have drawn up a specification, of which the *précis* is given in Table I (B.S.S. No. 383/1930).

The user who requires a gunmetal other than that covered by B.S.S.383 and wishes, quite legitimately, to buy on analysis and physical properties, is faced with the problem of drawing up his own specification or of adopting some other private specification which may not be quite suitable for a particular duty, or may, as is frequently the case, be deficient in one or more particulars which should be in every specification for a cast alloy to ensure material of good quality.

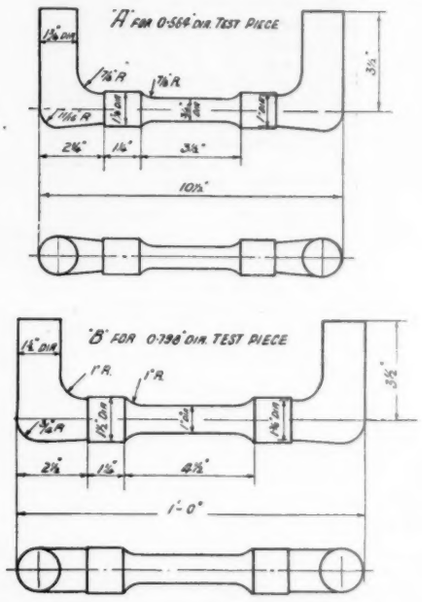

FIG. 1.—STANDARD CAST TEST-BARS FOR GUNMETALS, BRONZES AND PHOSPHOR-BRONZES.

TABLE I.—*British Standard Specification No.* 383—1930, *for* 2/10/88 *Bronze (Gunmetal) Castings for General Engineering Purposes.*

Analysis:		
Copper	.. ..	86.65—88.5 per cent.
Tin	.. .. ..	9.75—10.25 „
Lead	.. .. ..	0.50 maximum per cent.
Zinc	.. .. ..	1.75—2.25 per cent.
Nickel	.. .. ..	0.20 maximum per cent.
Other elements	..	0.15 maximum per cent.
Physical properties:		
Tensile strength	..	16 tons per sq. in. minimum.
Elongation	.. ..	8 per cent. minimum.

* Report presented at the Annual Conference of the Institute of British Foundrymen in Glasgow this week.

The result has been the production of a very large number of specifications of varying degrees of suitability, in many cases differing from one another in minor respects only. In the preliminary investigation conducted by the Sub-Committee it was found that no fewer than 37 specifications in current use by various purchasers fell within the range of composition given in Table II.

TABLE II.—*Range of Leaded Gunmetals Covered in* 37 *Specifications Examined.*

Copper	82—93 per cent.
Tin	4—9 „
Lead	0—7 „
Zinc	1—8 „

The necessity for constant variations in procedure to meet small points of difference in specifications for what are essentially similar materials is highly inefficient, and militates against the regular production of articles of uniformly good quality.

The Sub-Committee considers, therefore, that the interests of manufacturers and users would be well served by the standardisation of suitable compositions of leaded gunmetals which would cover the range of materials indicated in Table II and provide recognised and generally-used materials for duties where a gunmetal cheaper than Admiralty gunmetal would meet the needs adequately and possibly more effectively. Two compositions are indicated in the present report, which also contains the results of large numbers of tests carried out in various bronze foundries on selected alloys. In order that the results obtained in different foundries should be comparable, special forms of test-bar designed to give reproducible results were devised and the details of these test-bars, together with reasons which led to their adoption, are also indicated.

Test-Bar Preparation

In investigating the problem of suitable alloys to cover adequately the range indicated in Table II, it was found that much divergence of physical test data resulted from great difference in the manner of casting test-bars, both as regards the shape of these and the method of running them, and the character of the mould, *i.e.*, green sand and dry sand.

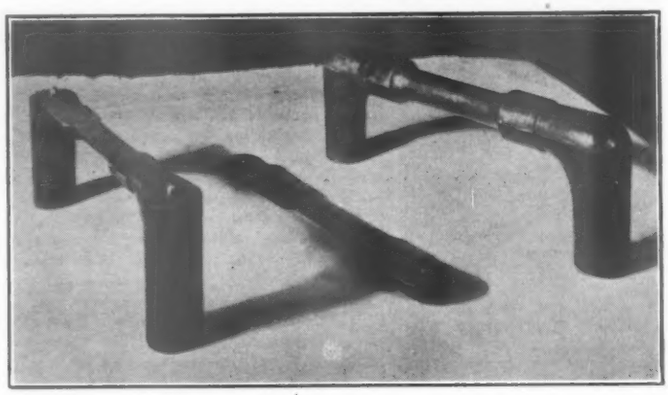

FIG. 2.—PATTERN FOR STANDARD TEST-BAR.

Much confusion of thought appears to exist on the subject of the function of test-bars in relation to cast non-ferrous alloys. There is no reason why test-bars, either cast "loose" or "attached," should necessarily give the same physical properties as would be found by cutting samples from the casting itself. Test-bars can only give an indication of the quality of the metal which has been used.

To obtain correct knowledge of the physical properties of the casting, it is necessary to cut test-pieces from the casting itself in various positions, which is an unnecessary and commercially impracticable procedure for the majority of non-ferrous castings.

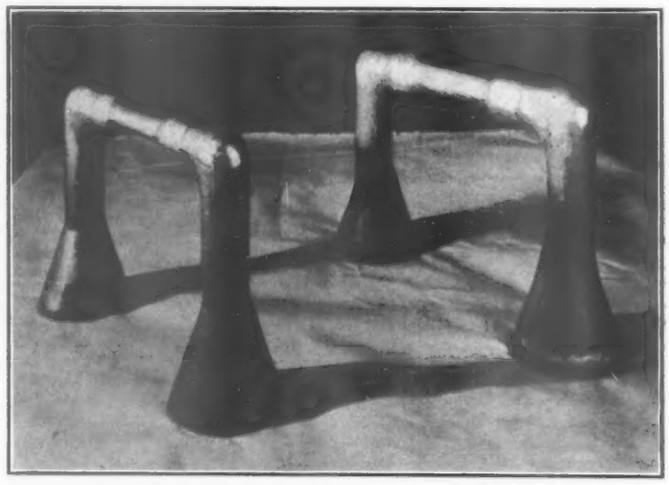

FIG. 3.—THE TEST-BARS AS CAST.

The selection of the most suitable type of test-bar and method of moulding and pouring should therefore be influenced not by an endeavour to obtain the highest physical properties possible, but by consideration of uniformity of results throughout the majority of foundries, and of methods not subject to wide variation in results due to slight variation in treatment. The test-bar and the method of casting should be capable of adoption by any foundry with the assurance of repetition of results obtained in other foundries. Studies of various test-pieces and methods of running in general use were made, and it was felt that most of these had been designed to give the highest test results possible (under carefully standardised and sensitive conditions), without due regard to the probable physical test results in the castings these bars were presumed to represent.

As indicated above, the Sub-committee have taken the view that it is futile to attempt to devise a test bar which will reproduce the physical characteristics of the related castings.

The Sub-committee has therefore decided to recommend a type of bar and method of casting the keynote of which is simplicity. This is illustrated in Fig. 1. Two sizes are shown, the smaller to turn to 0.564 in. in the effective gauge length, and the larger to turn to 0.798 in. in the effective gauge length. Both bars are suitable for turning to suit any normal type of testing machine grips, either wedge grips or collared ball seating grips.

TABLE III.—*Gunmetals—Composition.*

I.B.F. designation.	Specification.	Copper. Per cent.	Tin. Per cent.	Zinc Per cent.	Lead Per cent.
G.M.1	Admiralty Gunmetal (88:10:2) or B.S.I. 383/30	Remainder	9.75—10.25	1.75—2.25	0.0—0.50
			Min.	Max.	Max.
G.M.2	87 : 9 : 3 : 1 Gunmetal ..	Remainder	8 per cent.	4 per cent.	2 per cent.
G.M.3	85 : 5 : 5 : 5 Gunmetal ..	Remainder	5 per cent.	6 per cent.	6 per cent.

TABLE IV.—*Gunmetals—Physical Properties.*

I.B.F. designation.	Specification.	Maximum stress. Tons per sq. in.	Elongation. Per cent.
		Min.	Min.
G.M.1	Admiralty Gunmetal or B.S.I. 383/30 (88:10:2)	16	8
G.M.2	87 : 9 : 3 : 1 Gunmetal	14	14
G.M.3	85 : 5 : 5 : 5 Gunmetal	12	12

Material complying with the above tensile tests may be expected to give the following other physical properties:—

I.B.F. designation.	Specification.	Brinell hardness, 10 mm. per 1,000 kg.	Density (machined specimens).
G.M.1	Admiralty Gunmetal (88:10:2) or B.S.I. 383/30	65	8.50
G.M.2	87 : 9 : 3 : 1 ..	65	8.50
G.M.3	85 : 5 : 5 : 5 ..	60	8.55

It has been thought advisable to specify the dimensions of the ingate and riser for each size of bar and for normal use the Sub-committee recommend that these should be made integral with the pattern as shown in Fig. 2. It is recommended that the size of test-bar used to represent any particular batch of castings shall be that of which the cross section more nearly approaches the wall thickness of the casting concerned.

After careful study of the preliminary sets of tests on various alloys by members of the Sub-committee and prominent bronze foundries which agreed to carry out tests, it was decided that the alloys, the composition of which is shown in Table III, would meet all except very abnormal requirements for the gunmetals in the range stated in Table II other than Admiralty gunmetal (B.S.I. Spec. No. 383—1930). For convenience of comparison this alloy is shown in Table III. Table IV shows (B.S.I. Spec. No. 383—1930 included) the physical properties it is recommended be specified as minima for these alloys; the data on which these recommendations have been based are summarised in Table V.

Seven bronze foundries were asked to make a series of test-bars of these alloys—either in green or dry sand, or both, using the test-bars as shown in Fig. 1, and submit their results to the Non-Ferrous Sub-committee. They were asked also to cast both large and small bars at three different temperatures, these to be as near as possible to 1,200, 1,150 and 1,100 deg. C. This procedure in respect to casting temperature was adopted to give indication as to the influence of casting temperature on test results and to guide members of the Institute in any duplication or criticism of the results.

The complete schedule of results obtained by various members of the Sub-committee and co-operators is shown in Table V. Analyses of the alloys used by each co-operator have been purposely omitted but each co-operator has satisfied the Sub-committee that his alloy fell within the limits of Table III. Likewise no mention has been made as to whether all virgin or all scrap metal was used or a proportion of each. Having regard to the large divergence possible, both as regards composition within the limits of the specification and grade of metal used, the Sub-committee feels satisfied with the results obtained.

It is not felt that any useful purpose could be served by discussing the detailed results, since many details regarding the exact procedure which each investigator adopted are not available. The results are indicative of the results to be obtained under strictly works conditions, but naturally with some measure of control such as any well-ordered bronze foundry adopts to-day.

It has been thought advisable to include in the physical properties (though not for acceptance tests) both Brinell hardness and density as both these are simple inexpensive tests which the most modest of foundries and purchasers can adopt and which will give a very good indication (even without tensile test) of the quality of the material.

TABLE V.—*Summary of Physical Tests on G.M.2 and G.M.3.*

Works.	Maximum stress, tons per sq. in.						Elongation, per cent.						Type of mould.
	Large bar.			Small bar.			Large bar on 3 in.			Small bar on 2 in.			
	Casting temperature, deg. C.						Casting temperature, deg. C.						
	1,200	1,150	1,100	1,200	1,150	1,100	1,200	1,150	1,100	1,200	1,150	1,100	
G.M.2—													
A	16.6	18.0	17.6	16.4	14.0	15.6	28.0	26.0	21.0	25.0	10.0	12.0	Dry
A	18.0	17.6	17.2	15.2	18.0	18.4	35.0	25.0	20.0	17.0	23.0	32.0	,,
B	13.7	14.1	15.3	12.8	15.8	14.8	12.5	12.0	16.0	7.5	18.5	12.0	Green.
C	16.0	17.7	16.2	17.6	19.2	15.6	18.5	21.0	8.5	24.5	27.5	7.0	Dry.
C	15.8	15.6	15.2	18.8	18.0	17.6	15.0	13.0	14.0	30.0	23.5	12.5	Green.
D	—	17.2	—	—	16.5	—	—	24.0	—	—	17.5	—	Dry.
F	13.7	14.8	16.2	16.2	16.3	16.6	15.0	18.0	20.0	20.0	20.0	19.0	,,
G	11.5	12.9	18.5	16.4	16.8	17.0	18.0	11.0	33.0	20.0	23.0	27.0	,,
Average ..	15.0	16.0	16.6	16.0	16.8	16.5	20.0	19.0	18.9	20.5	20.0	17.3	—
G.M.3—													
A	12.8	13.2	11.0	9.6	9.6	11.2	18.0	18.0	11.0	11.0	10.0	14.0	Dry.
A	13.6	14.8	15.0	15.2	13.6	14.4	18.0	27.0	28.0	18.0	19.0	28.0	,,
B	15.5	12.9	16.0	14.4	14.6	14.8	16.5	13.0	27.0	20.0	21.0	21.5	Green.
C	14.2	15.6	16.4	16.8	16.0	18.0	12.0	18.0	18.0	16.0	13.0	19.0	Dry.
C	16.6	15.6	16.4	16.8	15.2	18.0	19.0	17.0	17.0	19.0	10.0	19.0	Green.
D	—	15.2	—	—	15.0	—	—	23.0	—	—	21.0	—	Dry.
F	12.1	13.8	12.5	12.9	14.2	12.6	12.0	17.0	16.0	15.0	16.0	16.0	,,
G	12.4	14.0	14.3	10.6	13.6	15.0	18.0	24.0	22.0	16.0	21.0	22.0	,,
Average ..	13.9	14.4	14.5	13.4	14.0	14.8	16.0	19.6	20.0	16.4	16.5	20.0	—

Summary of Brinell Hardness and Density Determinations.

Works.	Brinell hardness.						Density.						Type of mould.
	Large bar.			Small bar.			Large bar.			Small bar.			
	Casting temperature, deg. C.						Casting temperature, deg. C.						
	1,200	1,150	1,100	1,200	1,150	1,100	1,200	1,150	1,100	1,200	1,150	1,100	
G.M.2—													
A	65.5	68.8	72.4	59.5	71.0	72.4	8.46	8.66	8.79	8.52	8.66	8.84	Dry.
A	65.5	63.9	70.6	65.5	68.8	72.4	8.61	8.67	8.82	8.69	8.82	8.84	,,
C	79.3	80.4	87.3	75.3	84.9	89.7	8.64	8.69	8.79	8.70	8.77	8.92	,,
C	74.3	79.3	77.6	78.9	87.2	87.3	8.33	8.61	8.57	8.58	8.83	8.84	Green
D	—	89.0	—	—	77.0	—	—	8.62	—	—	8.65	—	Dry.
F	69.0	76.0	78.0	68.0	75.0	78.0	8.4	8.6	8.76	8.47	8.63	8.82	,,
G	62.4	70.6	76.5	82.6	78.3	72.4	—	—	—	—	—	—	,,
Average ..	69.3	75.4	77.0	71.6	77.4	78.7	8.49	8.64	8.74	8.59	8.73	8.85	—
G.M.3—													
A	62.4	55.8	56.8	54.3	56.3	58.1	8.5	8.66	8.8	8.57	8.71	8.88	Dry.
A	62.4	62.4	55.5	59.5	59.5	59.5	8.86	8.78	8.56	8.89	8.85	8.72	,,
C	76.3	76.3	72.5	75.3	77.3	80.4	8.67	8.72	8.85	8.78	8.83	8.89	,,
C	71.5	72.4	76.3	78.3	76.3	80.4	8.6	8.67	8.67	8.70	8.79	8.89	Green.
D	—	80.0	—	—	69.0	—	—	8.77	—	—	8.70	—	Dry.
F	60.0	63.0	68.0	62.0	64.0	69.0	8.43	8.59	8.81	8.44	8.66	8.83	,,
G	65.5	72.4	68.8	65.5	59.5	68.8	—	—	—	—	—	—	,,
Average ..	66.3	69.0	66.3	65.8	66.0	69.3	8.61	8.70	8.74	8.67	8.76	8.84	—

(*Concluded on page* 460.)

Composition and Its Effect upon the Properties of Mould and Core-Sand Mixtures at Elevated Temperatures*

By F. HUDSON

In a previous Paper† the author gave the results of an investigation into the properties of mould and core materials at elevated temperatures. This Paper outlined in a general way the properties which could be expected in the above materials during and after the casting operation, and from the results obtained it was apparent that there was room for considerable improvement.

The present Paper is a continuation of the first and takes the investigation a step farther, indicating possible practical methods for controlling the properties of mould and core materials at elevated temperatures. From a study of the previous results obtained it is obvious that the composition of the mould or coresand mixture in service has an important bearing upon the properties at elevated temperatures as well as the foundry technique employed. The remarkable effect, for example, of coal-dust additions in reducing expansion and preventing the abnormal increase in strength consequent on heating, in conjunction with an easier fettling operation, undoubtedly warrants further investigation. It is considered that the high-temperature characteristics of most green sands are infinitely preferable to those exhibited by dry sand and loam, and there is a vital need for improved physical properties at high temperatures in these latter materials.

Very often the foundryman falls back on dry sand when he wishes to be particularly assured of good results, and whilst the characteristics of dry sand may be excellent at room temperature, the same statement by no means applies during and after the casting operation. If the addition of coal dust is so effective for controlling the properties of green sand at elevated temperatures it is obvious that its application, or the application of carbonaceous matter in another form, might also be advantageous to dry-sand practice.

In the steelfoundry the question of the high-temperature properties of mould and core materials are of particular importance. From previous tests conducted with steelfoundry "compo," it is evident that this material is open to considerable improvement.

In this present Paper an effort has been made to indicate the effect of various additions to mould and core materials with the view of obtaining more suitable properties at elevated temperatures. An effort has been made to keep these additions within the realms of practical possibility and the Paper concludes with some remarks affecting foundry technique in relation to the main trend of the investigation. It is not proposed to describe the methods employed for test purposes as these are identical to those adopted for the original investigation and adequately outlined in the first Paper published. Furthermore, an effort has been made to keep to general remarks covering the trade as a whole rather than to deal with any particular branch.

In selecting the subject of the Paper it was felt that matter of fundamental nature was indicated, and obviously the effect of composition is a proper starting point. The question of density of ramming is not covered in the Paper, as this aspect is quite secondary. Furthermore, the author considers that any work on ramming control should be done by foundries for themselves, as individual practice entails such a host of variables which mitigates the value of a general research on the subject. It is also problematical as to whether ramming control will ever become a scientifically-controlled operation common to the whole industry, and unless this can be arranged, any work on the subject is more or less without immediate practical application.

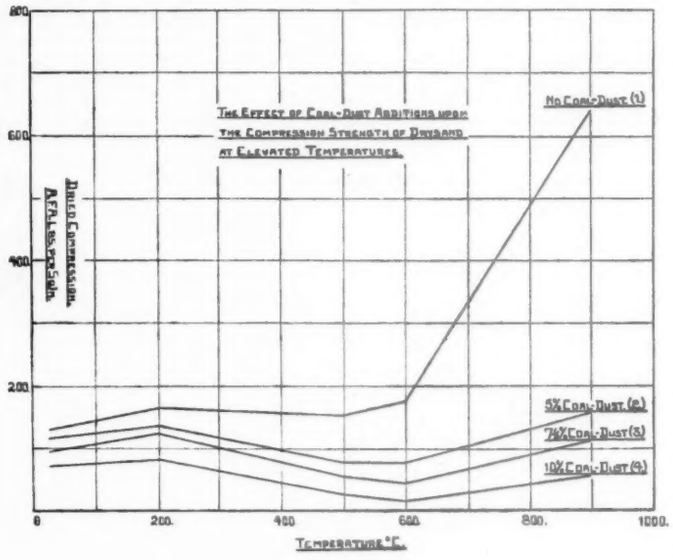
THE EFFECT OF COAL-DUST ADDITIONS UPON THE COMPRESSION STRENGTH OF DRYSAND AT ELEVATED TEMPERATURES.
DRIED COMPRESSION A.F.A. lbs. per Sq.in.
NO COAL-DUST (1)
5% COAL-DUST (2)
7½% COAL-DUST (3)
10% COAL-DUST (4)
TEMPERATURE °C.

FIG. 1.

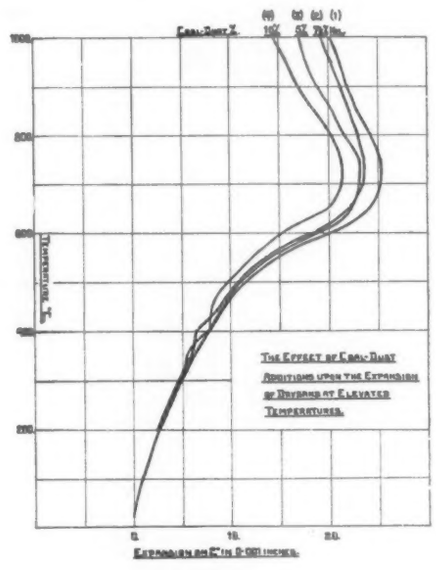

FIG. 2.

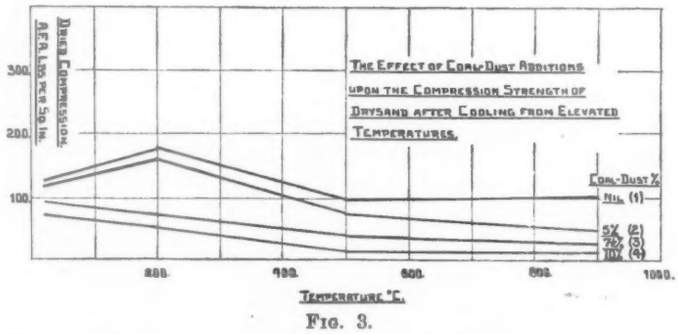
DRIED COMPRESSION A.F.A. Lbs. per Sq. in.
THE EFFECT OF COAL-DUST ADDITIONS UPON THE COMPRESSION STRENGTH OF DRYSAND AFTER COOLING FROM ELEVATED TEMPERATURES.
COAL-DUST %
NIL (1)
5% (2)
7½% (3)
10% (4)
TEMPERATURE °C.

FIG. 3.

TABLE I.—*Effect of Coal Dust Additions upon the Properties of Dry Sand at Atmospheric Temperatures.*

Mix. No.	Mixture composition.	App. den.	Per cent. moisture.	Compression strength. A.F.A. lbs. per sq. in.		Permeability. A.F.A. No.		Per cent. loss on ignition.
				Green.	Dried.	Green.	Dried.	
1.	30 per cent. reclaimed oil-sand cores, 69.25 per cent. dry-sand floor sand, 0.75 per cent. bentonite, no coal dust. (Milled 5-10 mins.)	1.69	8.0	4.6	128.5	61.5	87.0	4.77
2.	As above, plus 5 per cent. coal dust ..	1.61	7.8	5.9	116.5	60.0	81.0	8.90
3.	As above, plus 7½ per cent. coal dust ..	1.57	7.9	5.5	94.4	58.0	78.0	9.61
4.	As above, plus 10 per cent. coal dust ..	1.52	7.5	5.3	73.6	44.0	59.0	12.62

* Paper presented at the Annual Conference of the Institute of British Foundrymen in Glasgow this week.

† "Some Properties of Mould and Core Materials at Elevated Temperatures," FOUNDRY TRADE JOURNAL, December 5, 1935.

APPERTAINING TO BRASS AND IRON FOUNDING

The Effect of Coal Dust Additions

In order to investigate the effect of coal-dust additions upon the properties of mould and core-sand mixtures at elevated temperatures, the base mixture employed was of the dry-sand type. Dry sand was adopted as a base for the very obvious reason that upon the addition of certain percentages of coal dust it automatically changes into the green-sand class, and consequently the final results obtained cover both types of sand.

Reference to Table I shows the sand mixtures employed and their physical properties at atmospheric temperature. It will be observed that the investigation covers the properties of an ordinary dry sand to which has been added 5, 7½ and 10 per cent. additions of a superfine coal dust containing around 35 per cent. volatile matter. At atmospheric temperature the effect of increasing additions of coal dust upon the physical properties of the sand under standard ramming conditions tends to:—

(1) Decrease the apparent density.

(2) Increase the green-compression strength. (There appears to be a certain percentage of coal dust which produces optimum green-compression strength. In this case the highest strength value was obtained with 5 per cent. coal-dust additions, and further additions caused a slight reduction in strength.)

(3) Decrease the dried-compression strength.

(4) Decrease the permeability in both the green and dried state.

(5) Increase the percentage loss on ignition or gas evolved.

The effect of the coal-dust additions upon the properties of the sand mixtures at elevated temperatures is shown in Figs. 1, 2 and 3. Considering Fig. 1 first, it will be noticed that the addition of coal dust to dry sand most markedly prevents the large increase in dried-compression strength common to many mould and core compositions. The dry-sand base mixture employed, relatively free from coal dust, has a dried-compression strength value of 640 lbs. per sq. in. at 900 deg. C. Upon the addition of 5 per cent. coal dust this figure is reduced down to 160 lbs. per sq. in. and then subsequently down to 112 and 54 lbs. per sq. in., with 7½ and 10 per cent. additions respectively.

Similarly, the addition of coal dust reduces the total expansion of the sand at 1,000 deg. C., as indicated in Fig. 2, from 0.152 in. per ft. down to 0.128 in., and also promotes easier removal of the sand after the casting operation has been completed, as shown in Fig. 3.

In view of these results, it is suggested that the addition of coal dust to dry-sand mixtures will impart superior physical properties to the sand at elevated temperatures. Its addition will prevent the large increase in strength common to many sands when heated, and this will undoubtedly promote safer casting production. At the same time, fettling costs will be reduced considerably. The effect of coal dust upon the expansion of mould and core materials is perhaps disappointing, and its action in decreasing the permeability, in conjunction with an increase in gas evolution, warrants care being taken in this direction. In an attempt to overcome these latter deficiencies further additions were tried, and the most likely appeared to be sawdust.

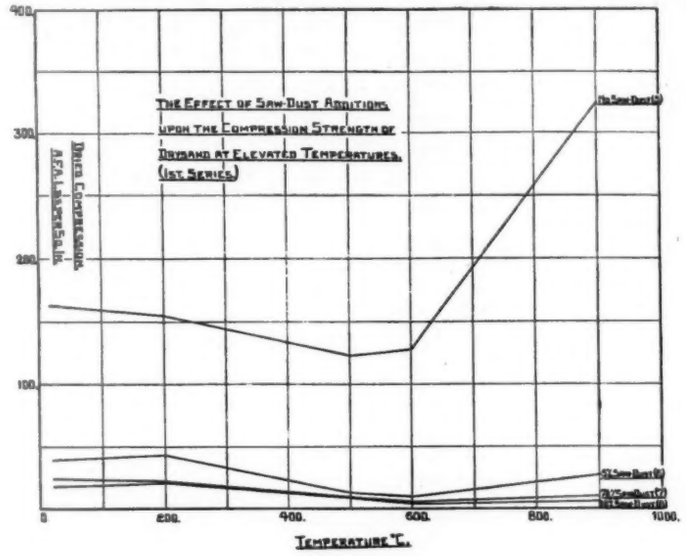
THE EFFECT OF SAW-DUST ADDITIONS UPON THE COMPRESSION STRENGTH OF DRYSAND AT ELEVATED TEMPERATURES. (1ST. SERIES.)
DRIED COMPRESSION. A.F.A. LBS. PER SQ. IN.
TEMPERATURE °C.

FIG. 4.

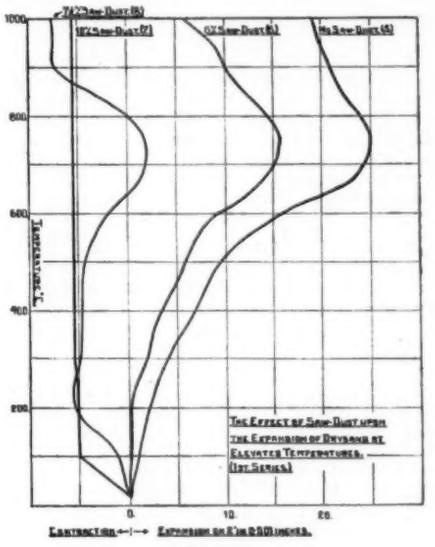
THE EFFECT OF SAW-DUST UPON THE EXPANSION OF DRYSAND AT ELEVATED TEMPERATURES. (1ST. SERIES.)
TEMPERATURE °C.
CONTRACTION ←|→ EXPANSION IN INCHES PER FOOT

FIG. 5.

Effect of Sawdust Additions

The tests previously described were repeated, substituting sawdust for the coal dust, and the properties at atmospheric temperature of the mixtures produced are shown in Table II. It will be observed that the effect of sawdust upon a dry-sand mixture under constant ramming conditions causes:—

(1) Large decrease in apparent density.

(2) Decreases the green compression strength.

(3) Large decrease in dried compression strength.

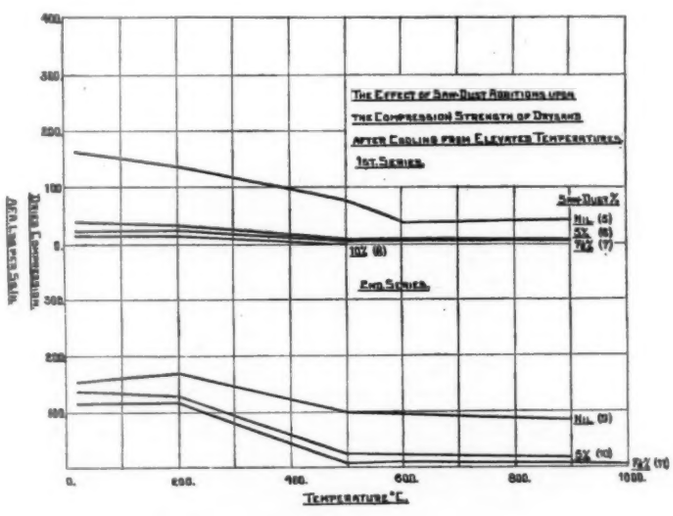
THE EFFECT OF SAW-DUST ADDITIONS UPON THE COMPRESSION STRENGTH OF DRYSAND AFTER COOLING FROM ELEVATED TEMPERATURES. 1ST. SERIES.
DRIED COMPRESSION. A.F.A. LBS. PER SQ. IN.
TEMPERATURE °C.

FIG. 6.

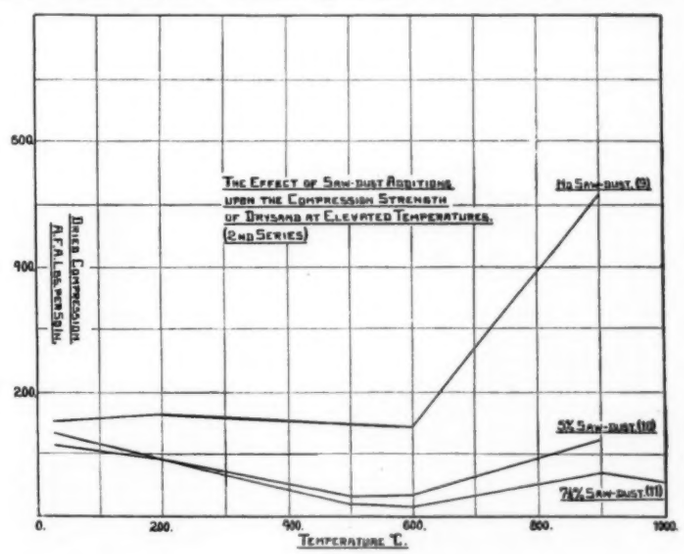
THE EFFECT OF SAW-DUST ADDITIONS UPON THE COMPRESSION STRENGTH OF DRYSAND AT ELEVATED TEMPERATURES. (2ND SERIES)
DRIED COMPRESSION. A.F.A. LBS. PER SQ. IN.
TEMPERATURE °C.

FIG. 7.

(4) Increases the permeability in both the green and dried state.

(5) Increases the percentage loss on ignition or gas evolved.

The outstanding characteristics in the sawdust-bearing sand over the coal-dust additions, so far as the properties at atmospheric temperatures are concerned, appear to be connected with dried compression strength and permeability.

TABLE II.—*Effect of Sawdust Additions upon the Properties of Dry Sand at Atmospheric Temperatures.*

Mix. No.	Mixture composition.	App. den.	Per cent. moisture.	Compression strength. A.F.A. lbs. per sq. in.		Permeability. A.F.A. No.		Per cent. loss on ignition.
				Green.	Dried.	Green.	Dried.	
	1st Series.							
5.	30 per cent. reclaimed oil-sand cores, 69.25 per cent. dry-sand floor sand, 0.75 per cent. bentonite, no sawdust. (Milled 5-10 mins.)	1.68	7.6	4.5	163.2	57.0	72.0	4.76
6.	As above, plus 5 per cent. sawdust ..	1.46	9.1	3.6	40.0	73.0	118.0	8.11
7.	As above, plus 7½ per cent. sawdust ..	1.38	9.4	3.9	24.0	69.0	130.0	10.13
8.	As above, plus 10 per cent. sawdust ..	1.31	10.2	3.5	17.6	73.0	140.0	13.54
	2nd Series.							
9.	30 per cent. reclaimed oil-sand cores, 69.25 per cent. dry-sand floor sand, 0.75 per cent. bentonite, no sawdust. (Milled 5-10 min.)	1.66	7.5	4.5	154.2	—	104.0	4.99
10.	30 per cent. reclaimed oil-sand cores, 63.5 per cent. dry-sand floor sand, 1.5 per cent. bentonite, 5 per cent. coarse sawdust. (Milled 5-10 mins.)..	1.55	11.1	5.3	136.3	—	93.0	7.21
11.	30 per cent. reclaimed oil-sand cores, 60.5 per cent. dry-sand floor sand, 2 per cent. bentonite, 7.5 per cent. fine sawdust. (Milled 10 mins.) ..	1.51	15.7	4.2	115.2	34.0	119.0	9.30

Note.—Mixture No. 11 contained the sawdust in the form of wood flour. In all other cases ordinary patternshop waste product was employed.

The addition of sawdust causes a much larger decrease in the dried strength than when coal dust is used, but produces a much more permeable sand. In view of the effect of sawdust in causing excessive reduction in dried strength, it is obvious that this aspect must receive further consideration which led to the investigation of a second series of sawdust-bearing

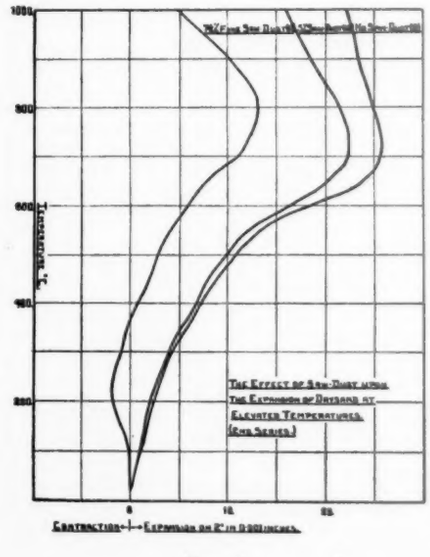

FIG. 8.

sands containing extra bond. The mixtures and properties of this second series are also indicated in Table II. It will be observed that the increase in permeability is maintained in the dried state, although the green permeability value has been decreased, due to the additional bond. In this respect it is interesting to note that, in connection with mixture No. 11, containing 7½ per cent. fine sawdust, whilst the green permeability number was only 34 A.F.A., it increased to 119 on drying.

The effect of sawdust additions in respect to the properties at elevated temperatures are shown for the first series in Figs. 4, 5 and 6, and for the second series in Figs. 7, 8 and 6.

It will be observed that the additions of sawdust act in a similar manner to coal dust, preventing the large increase in strength on heating, and promote easier removal of the sand after casting. The most remarkable effect, however, is in connection with the problem of expansion. In this respect sawdust has a much greater action than coal dust, as it reduced the amount of expansion in Series No. 1 from 0.150 in. per ft. at 1,000 deg. C., progressively down to an actual contraction of 0.032 in. per ft. with the 10 per cent. addition. Even in Series No. 2, using the more heavily-bonded sand, the reduction in expansion was most marked.

It can consequently be concluded that sawdust additions impart better high-temperature characteristics to mould and core materials than does coal dust. In fact, mixture No. 11 has a particularly good range of properties both at atmospheric and elevated temperatures, and is very suitable for casting production in dry-sand moulds. Moulds made in such a sand will definitely tend to prevent the formation of buckles and surface scabs, minimise the tendency for cracked castings, and inherent strain, and also give extremely easy fettling conditions.

(To be continued.)

Dust in Industry

The Air Hygiene Foundation of America, which was formed in 1935 by a large group of companies from various manufacturing fields, having for its object the improvement of dust conditions in industries, held its first annual meeting in Pittsburgh recently. The medical committee reported on its programme of collecting and evaluating available information relating to industrial dust diseases and disabilities resulting therefrom, described the amount and character of research now being carried on, and particularly what phases may involve duplication of effort or should be extended, and presented an outline of the type of medical control for the proper protection of employer and employee alike. The opportunities for fruitful research are apparent, it was emphasised at the meeting, in view of the present knowledge of the cause, control and prevention of pneumoconiosis (silicosis) in the industries.

The Tata Company

INCREASED PRODUCTION

The financial report of the Tata Iron & Steel Company, Limited, for the year ended March 31 last includes references to the output figures for the principal products of the company. The output of coke in 1934-35 and 1935-36 was 726,000 tons and 730,000 tons respectively; of pig-iron 892,000 and 900,000 tons; of steel ingots 834,000 and 880,000 tons; and of saleable steel 604,000 and 646,000 tons respectively. The production was the highest so far attained in any one year. An increased output was recorded in practically all products. The production of high-tensile steel, mostly for wagon building, was continued.

The equipment in the works was maintained in first-class condition throughout the year and many improvements were made. The second new unit at the sheet mills, which was brought into operation in March, 1935, has contributed largely to the increased production of saleable steel during the year. The coal-mixing bunkers at the coke ovens came into operation in June, 1935, and have facilitated the blending of the various coals and led to better control of the coke plant. The construction of the new battery of coke ovens and new by-product plant has proceeded satisfactorily, and it is expected that the first coke will be made in the new ovens in December, 1936.

"E" Blast Furnace was entirely rebuilt and new stoves provided. The capacity of the furnace is about 750 tons per day, and it is hoped to blow in the new furnace very shortly. The normalising plant at the plate mill was installed and is now ready for operation, while an electric furnace was installed at the foundry, which will enable the works to meet its numerous requirements of small steel castings.

The despatches from the company's properties in 1934-35 and 1935-36 were:—Iron ore, 1,429,000 and 1,449,000 tons respectively; limestone, 30,000 and 40,000 tons; dolomite, 19,000 and 63,000 tons; manganese ore, 4,000 and 15,000 tons; fireclay, 7,000 and 6,000 tons; miscellaneous minerals, 10,000 and 14,000 tons; total, 1,499,000 tons and 1,587,000 tons respectively. Coal despatched from the company's collieries in 1934-35 and 1935-36 totalled:—Jamadoba, 415,000 tons and 338,000 tons, and Malkera-Choitodih, 132,000 and 114,000 tons respectively. The company's other collieries remained closed during the year.

Recommendations for Two Leaded Gunmetals

(*Concluded from page* 457.)

The introduction of density figures is somewhat novel, but this test is of great and insufficiently-appreciated value in cast non-ferrous alloys, and can be easily applied to a variety of forms and pieces. The method recommended for ascertainment of density is the simple one of weighing in air and then in water. Weighing in paraffin to avoid formation of air bubbles clinging to the specimen is sometimes an improvement. By the usual formula and using a reasonably sensitive balance results accurate to the first place of decimals can readily be obtained.

The density of the alloys concerned is not seriously affected by variation in composition but very largely by quality of metal, melting practice and casting temperature.

In the particular series under discussion samples varying from 7.9 to 8.9 have been examined by the Sub-committee, the former representing porous and weak metal and the latter close dense material resulting from chill casting in small sections.

The Sub-committee is very anxious to obtain the fullest expression of opinion on these recommendations both from makers and users with a view to making representations in the proper quarters for their adoption as standards subject to any modifications that may be deemed advisable after all opinions have been secured.

The Free and Hindered Contraction of Alloy Cast Steels*

By C. W. BRIGGS and R. A. GEZELIUS, Washington, D.C.

A study of the contraction taking place in the cooling of steel castings from the solidifying temperature of the steel to room temperature was first made by Körber and Schitzkowski.[1] Their data, however, were rather incomplete, since various observations seem to indicate that changes in the carbon content of cast steel are responsible for variations in the linear contraction.

In the second publication of the series,[2] a study was made of the free and hindered contraction of cast steels of varying carbon contents. The following principles of a fundamental nature were disclosed by the data:—

(*a*) The total amount of free contraction of cast carbon steel decreases as the carbon content of the steel increases. The contraction varies from 2.47 per cent. for 0.08 per cent. to 2.18 per cent. for 0.90 per cent. carbon steel.

(*b*) The total amount of contraction occurring while cooling to the critical range, in the case of the freely contracting bar, decreases as the carbon content of the steel increases.

(*c*) The amounts of contraction obtained after the freely contracting bars have passed through the critical range are approximately equal.

(*d*) In the cases of the freely contracting bars and the bars hindered slightly while contracting, the carbon content influences the rate of contraction markedly until the bars have contracted approximately 0.10 per cent.

(*e*) Bars hindered while cooling, contract similarly to the freely contracting bars in that, at any temperature prior to the critical range, the amounts of contraction increase with decreasing carbon contents.

(*f*) The total amounts of hindered contraction increase as the carbon content increases.

(*g*) The percentage of the total contraction occurring before the critical range is reached decreases as the tension restraining the bar increases.

(*h*) The data obtained, when the contraction was hindered by the lightest spring, represent approximately the stresses encountered by the average commercial casting as the total contraction under this tension approximates the "patternmaker's shrinkage" of $\frac{5}{16}$ in. per ft.

(*i*) Slight variations from the normal manganese or silicon content of cast carbon steel do not result in measurable differences in the rate of the total amount of free or hindered contraction.

(*j*) The contraction taking place upon the solidification of cast steel, as approximated from the data available at present, is 2.7 per cent.

(*k*) The rate of contraction, as well as the strength of the steel, may influence the formation of hot tears in steel castings.

The data thus pointed out that, by varying the carbon content, different amounts of contraction could be obtained. Since the carbon content was so influential in bringing about changes in contraction, it appeared likely that alloy additions would also change the characteristics of free and hindered contraction. Also, various conflicting opinions as to the effect of alloying elements upon contraction have been presented by members of commercial organisations, thereby pointing out the need for basic information on this subject.

In planning the research on contraction of cast alloy steels, it was deemed necessary to maintain the carbon content at approximately the same percentage in all of the alloys studied. This was necessary to ascertain the effect of the alloy additions. Thus, the chemical analyses of the cast steels studied may differ slightly from those usually employed by the industry. It was planned, however, to use alloy additions comparable to those found in commercial practice.

Several prominent steel founders were solicited with regard to typical compositions and from their replies a set of eleven alloy cast steels was prepared, studied, and compared with the contraction of the standard carbon cast steel. The carbon content chosen as a standard was 0.35 per cent. This figure was adopted since a large number of commercial cast steels call for a carbon content of 0.35 per cent. and a cast carbon steel had already been studied with this amount of carbon present. The manganese and silicon were maintained at approximately 0.75 per cent. and 0.35 per cent. respectively, unless they were being used in the capacity of an alloy. The phosphorus and sulphur were kept below 0.04 per cent.

Methods Used in Testing

The procedure used in collecting the data on the free and the hindered contraction of alloy cast steels was similar to that employed in obtaining the data on plain carbon cast steels.

Bar Design.—The bar that was used in this study has large ends and a small central section fed by a horn gate, as it was deemed necessary to have a bar that cooled uniformly along its axis. The bars, as cast, were 26 in. long with a diameter at the centre of $1\frac{9}{16}$ in. (a cross-sectional area of 2 sq. in.) and a diameter at the ends of $2\frac{1}{4}$ in. Sections $1\frac{3}{4}$ in. in diameter and 2 in. long, which acted as clamps on the stainless steel bolts, were at the ends of the bar and cast integrally with it.

Type of Sand.—The sand used was a synthetic green sand made up with No. 40 washed silica sand as a base and mixed in the following proportions by volume:—500 parts silica, 19 parts Bentonite; one part cereal binder, and 5 per cent. water (by weight). The mixture was mulled for five minutes and the following properties were obtained:—

Permeability	... ...	180 cc. per min.
Compression strength	...	3.5 lbs. per sq. in.
Shear strength	... ...	nil.
Tensile strength	... ...	nil.

The sand was reclaimed after it had been used. The properties of the reclaimed sand were approximately the same as those of a newly prepared sand.

Moulding Procedure.—Steel flasks 36 in. long and 10 in. wide were constructed of 5-in. channel iron and used as the mould containers. The sand was rammed lightly to a mould hardness number of about 50. A horn gate varying from 2 in. to $\frac{3}{4}$ in. in diameter was used for the pouring gate. The $\frac{3}{4}$-in. section, where the steel enters the mould cavity, was much smaller than the contraction bar at this point and hence froze before the bar, permitting no feeding during the solidification of the bar.

A relieving block $1\frac{1}{2}$ in. square, shaped similarly to the horn gate, was moulded a short distance away from the horn gate. This block was removed from the mould and, when the hindered bars contracted, the horn gate was able to move freely without being restricted by the moulding sand. The surface of the mould cavity was not covered with a mould wash.

Assembling the Mould.—A stainless steel bolt was placed in each end of the flask. One bolt tied the bar down to the flask and the other was fastened to the flat steel spring. The bolts were $\frac{7}{8}$-in. in diameter and had a shank of 4 in. and a body of 5 in. Two grooves $\frac{3}{8}$-in. wide and $\frac{1}{4}$-in. deep were machined in the body end of the bolt. This permitted the metal, upon solidifying around the bolts, to have a strong grip on them. The chilling action was so great that the bolts did not fuse into the cast metal.

A small quartz thermocouple protecting tube was run through the cope of the mould $1\frac{1}{2}$-in. from the end of the bolt that tied the cast bar down to the flask. This tube extended to the axis of the bar and the readings obtained by the platinum and platinum-rhodium thermocouple represented the temperature of the bar throughout the central 26 in.

The flat springs used were made from heat-treated spring steel, 2-in. by $10\frac{1}{2}$-in. with the following thicknesses:—

Spring No.	Thickness, in.
"*C*"	$\frac{7}{8}$
"*G*"	$\frac{25}{32}$
"*E*"	$\frac{3}{8}$

The springs were calibrated very carefully in lb., total load.

Ames dials, held by an arm bolted to the end of the flask, were used to measure the amounts of contraction. A 16 mm. film moving picture camera, operated by a synchronous motor, recorded the amount of shrinkage and the temperature every 15 seconds. The temperature was recorded by a pyromillivoltmeter with a temperature range of 0 to 1,600 deg. C. The contraction was measured by Ames dials graduated to read to 0.001 in. The true free contraction of the bar was obtained with both ends of the bar free and two Ames dials to record the contraction. The runner box, which was used for convenience during pouring, was slotted at the base so that the excess metal would run out and not act as a feeding head or restrict contraction.

Type of Steel.—The steels were made in a 500 lb. per hr., Swindell, 3-phase, electric-arc furnace. The basic double-slag practice was used entirely during the collecting of the data presented in this report. In all cases, the steel-making conditions were duplicated as nearly as possible so that the data obtained could be carefully checked.

Pouring.—The steel was poured from a teapot ladle so that the slag had very little opportunity to enter the mould. The pouring temperature of the steel entering the mould was between 1,582 deg. C. and 1,538 deg. C. Aluminium, in amounts equivalent to 500 grams per ton, was added to the ladle prior to pouring.

Recording and Duplicating of Data.—After the bars had cooled to room temperature, the films, giving a photographic record of the temperature and shrinkage, were developed, projected, and the readings recorded. Each time the contraction studies were made, the data were taken in duplicate. This required a set of eight moulds to duplicate the four types of contraction. The results obtained were in excellent agreement; in fact, the discrepancies recorded were less than the average error indicated in the previous publication. When the differences in the results obtained with any alloy composition did not fall within the limits of error that had been arbitrarily set, the experiment was repeated and new data were obtained.

Shortly after the data were presented on the free and hindered contraction of carbon steels, a steel foundry executive pointed out that the data were collected, quite correctly, from steel poured within a relatively narrow temperature range. Since pouring temperature can vary considerably, it was deemed advisable to study the free and hindered contraction of the same heat

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* A Paper published by permission of the American Navy Department and presented to the American Foundrymen's Association. The authors are respectively Metallurgist, and Assistant Metallurgist to the U.S. Naval Research Laboratory.

1 Körber, F., and Schitzkowski, G., "Beitrag zur Schwindung von Stahlguss," Stahl und Eisen, p. 129 (1928).

2 Briggs, C., and Gezelius, R., "Studies on the Solidification and Contraction in Steel Castings II—Free and Hindered Contraction of Cast Carbon Steel," Trans. A.F.A., vol. 42, pp. 449–476 (1934).

of steel poured at high and low temperatures. One set of bars was, therefore, cast at approximately 1,605 deg. C. and another set at approximately 1,440 deg. C., a difference of 165 deg. C. in pouring temperature. The plotted data were very close together, within the limits of error of the test, and the final end-points were practically identical. This points out, as was expected, that the differences in pouring temperature had no effect on the duplication of the data or on the final results.

Data Obtained

Types of Alloy Steels.—Studies were made of the free and the hindered contraction of the alloy steels listed in Table I. A glance at the table will be sufficient to observe that only a small number of the many commercial alloy combinations have been studied. However, most of the single alloy steels and several important dual combinations are reported.

TABLE I.—*Analyses of the Alloy Cast Steels.*

Steel no.	Type.	Per cent. C	Mn	Si	Ni	Cr	Cu	Mo	V
1	Carbon	0.35	0.74	0.37	—	—	—	—	—
2	Manganese	0.32	1.32	0.41	—	—	—	—	—
3	Nickel	0.34	0.64	0.41	3.00	—	—	—	—
4	Chromium	0.35	0.75	0.35	—	1.03	—	—	—
5	Copper	0.36	0.72	0.35	—	—	1.39	—	—
6	Molybdenum	0.37	0.77	0.35	—	—	—	0.39	—
7	Vanadium	0.32	0.65	0.37	—	—	—	—	0.25
8	Manganese-silicon	0.36	1.35	1.15	—	—	—	—	—
9	Nickel-manganese	0.32	1.24	0.30	1.46	—	—	—	—
10	Manganese-molybdenum ..	0.35	1.18	0.30	—	—	—	0.37	—
11	Manganese-vanadium ..	0.37	1.41	0.30	—	—	—	—	0.16
12	Nickel-chromium	0.37	0.73	0.34	2.88	0.91	—	—	—

Freely Contracting Bars.—The data obtained from the freely contracting bars are given in Table II. The data, unfortunately, fall so close together that it was found impossible to show all of the curves in one chart. It was, therefore, necessary to classify them by chemical composition and to show them in four charts. The data for each type of contraction, however, will be considered as a unit. Perhaps the most outstanding feature exhibited by the data is the fact that the plain 0.35 per cent. carbon steel contracts more than the alloy steels studied. It is true, however, that the differences between the total contraction of the various alloys are small. A further study of Table II reveals that, between

TABLE II.—*Data on Freely Contracting Alloy Cast Steel Bars.*

Steel no.	Type.	Per cent. contraction before critical range.	Per cent. expansion passing through critical range.	Per cent. contraction after critical range.	Per cent. total contraction.
1	C ..	1.47	0.10	1.03	2.40
2	High Mn	1.74	0.26	0.88	2.38
3	Ni ..	1.72	0.20	0.87	2.40
4	Cr ..	1.46	0.14	1.02	2.34
5	Cu ..	1.49	0.14	1.00	2.35
6	Mo ..	1.65	0.04	0.72	2.33
7	V ..	1.40	0.09	1.02	2.32
8	Mn-Si ..	1.54	0.14	0.96	2.35
9	Ni-Mn ..	1.70	0.19	0.86	2.37
10	Mn-Mo ..	1.68	0.02	0.66	2.32
11	Mn-V ..	1.50	0.13	0.96	2.33
12	Ni-Cr ..	1.95	0.04	0.36	2.27

the solidifying temperature and the critical range, the nickel-chromium steel contracted the most and the vanadium steel the least, while between the critical range and room temperature the vanadium, chromium and carbon steels contracted the most and the nickel-chromium steel the least. The amount of expansion occurring during the critical range was extremely low in the case of the molybdenum alloys, while the manganese steel expanded the most. In general, the contraction curves of the various freely contracting alloy steels are practically parallel prior to the critical temperature range, with the nickel-manganese and the carbon steel contracting the most and the molybdenum and nickel-chromium alloy the least. The maximum variation, except through the critical ranges, is only about 0.08 per cent. at any one temperature.

In Table VI the critical temperatures of the freely contracting alloy steels are tabulated. All of the alloy steels studied, except the vanadium steel, have critical temperatures lower than that of the carbon steel. In general, it may be said that the lower the critical temperatures, the greater is the amount of contraction prior to the critical. A very interesting fact to be noted is the very slight expansion of the molybdenum alloy steels while passing through the critical range.

The maximum variation between the curves after the critical range is of the same order as that which exists prior to the critical range; that is, if the nickel-chromium alloy steel is disregarded. The nickel-manganese steel alternates with the carbon steel in the upper position until a low temperature is reached when, due to a decrease in the rate of contraction, it drops to the third position. The nickel steel contracts practically the same amount as the carbon steel. The nickel-chromium steel has the least amount of contraction; this is probably due to the low temperatures of its critical range.

Light Hindered Contraction ("E" Spring).—It has previously been explained that, in the study of hindered contraction, the bars were restrained from contracting by springs of three different sizes. These springs were used to cause tensions in the bars similar to those encountered by castings. The conditions presented by these springs may not be comparable in magnitude to the stresses actually encountered in commercial castings, but they do give an indication as to the effects due to restricted contraction. The values in lbs. per sq. in. derived were computed for the smallest diameter of the bar which has a cross-sectional area of 2 sq. in.

The data obtained with the light "E" spring probably represent more closely the stresses encountered by the average commercial casting for the total contraction recorded under this tension approximates the "patternmaker's shrinkage" of $\frac{3}{16}$ in. per ft. (1.56 per cent.).

The hindered contraction data obtained from bars restrained by the light "E" spring are given in Table III. It may be noted in Table III that the carbon steel reference curve now exhibits a low total contraction of 1.64 per cent. as compared to most of the alloy steels which range from 1.58 to 1.78 per cent. with the molybdenum steel exhibiting the most contraction and the nickel-manganese and the manganese the least. The table also indicates that the nickel-chromium steel had the largest amount of contraction prior to the critical range, while the vanadium alloy contracted the least. After passing through the critical range, the nickel-chromium steel contracted very little, due undoubtedly to its low critical temperature. The molybdenum and manganese-molybdenum steels exhibited very little expansion during the critical range, though it was considerably more than that obtained when the bars were contracting freely.

An examination of the curves derived showed that there was a decided bend at about 950 deg. C. indicating that a marked change appeared in the rate of contraction at about this temperature. The variation between the upper and lower contraction curves indicated a difference in stress equivalent to about 250 lb. per sq. in. at 1,300 deg. C. and about 350 lb. per sq. in. at 1,000 deg. C. Thus, while the bend of curves

TABLE III.—*Data on Alloy Cast Steel Bars Restrained by Light "E" Spring.*

Steel no.	Type.	Per cent. contraction before critical range.	Per cent. expansion passing through critical range.	Per cent. contraction after critical range.	Per cent. total contraction.
1	C ..	0.92	0.18	0.90	1.64
2	High Mn	1.12	0.27	0.73	1.58
3	Ni ..	1.13	0.25	0.75	1.64
4	Cr ..	0.93	0.24	0.97	1.65
5	Cu ..	0.99	0.19	0.90	1.70
6	Mo ..	1.28	0.10	0.61	1.78
7	V ..	0.90	0.15	0.93	1.67
8	Mn-Si ..	1.03	0.20	0.88	1.72
9	Ni-Mn ..	1.06	0.26	0.76	1.58
10	Mn-Mo ..	1.25	0.09	0.57	1.72
11	Mn-V ..	1.08	0.22	0.85	1.72
12	Ni-Cr ..	1.48	0.14	0.26	1.60

appears to be fairly wide, the actual difference in the stress on the bars at any one temperature is rather low.

The manganese-vanadium steel has the greatest amount of contraction prior to the critical, but it is followed closely by the molybdenum and manganese-molybdenum steels. The lowest rate of contraction alternates between the manganese, the nickel-manganese and the carbon steels.

The critical temperatures for the bars restrained by the light "E" spring are given in Table VI. In general, about one-half of the steels have critical points that are slightly lower in temperature than those recorded when the bar was contracting freely. The critical range of the nickel-chromium steel again exhibits the lowest temperature, while the highest critical temperature is recorded by the vanadium steel.

The differences between the curves showing the greatest and the least contraction after the steels have passed through the critical range are about 1.5 times those found above the critical

TABLE IV.—*Data on Alloy Cast Steel Bars Restrained by Medium "G" Spring.*

Steel no.	Type.	Per cent. contraction before critical range.	Per cent. expansion passing through critical range.	Per cent. contraction after critical range.	Per cent. total contraction.
1	C ..	0.46	0.24	0.71	0.92
2	High Mn	0.60	0.33	0.64	0.90
3	Ni ..	0.56	0.28	0.61	0.89
4	Cr ..	0.41	0.21	0.78	0.99
5	Cu ..	0.49	0.21	0.73	1.01
6	Mo ..	0.67	0.14	0.52	1.05
7	V ..	0.45	0.11	0.64	0.98
8	Mn-Si ..	0.56	0.22	0.70	1.01
9	Ni-Mn ..	0.55	0.28	0.58	0.86
10	Mn-Mo ..	0.64	0.10	0.50	1.03
11	Mn-V ..	0.55	0.24	0.69	1.00
12	Ni-Cr ..	0.87	0.20	0.21	0.88

range. The nickel-manganese steel is in the lowest position and the manganese-vanadium and the molybdenum steels shows the greatest amount of contraction. The rate of contraction of the manganese-vanadium steel falls off rapidly within the 200 deg. C. to room temperature zone. This is a rather peculiar effect, although it is not exceptional, as approximately the same condition is found to exist with the nickel, manganese, and nickel-chromium alloy steels.

Medium Hindered Contraction ("G" Spring).—The data recorded with the medium "G" spring probably approximate conditions existing

in castings which, due to design or to unusually high mould resistance, are unable to contract appreciably.

The data pertaining to the bars hindered by the medium "*G*" spring are set forth in Table IV. The total contraction varies from 0.88 per cent. for the nickel-chromium steel to 1.05 per cent. in the case of the molybdenum steel. This contraction corresponds to a stress of from 6,150 to 7,350 lb. per sq. in., respectively. The 0.92 per cent. contraction of the carbon steel is very nearly the lowest amount of contraction recorded.

The different critical temperatures, as shown on Table VI, are again generally responsible for the different amounts of contraction before and after the critical range. The chromium steel has the least contraction before, and the most after the critical range, whereas the nickel-chromium steel, because of its low critical temperature, has most of its contraction prior to the critical range. The greatest expansion during the critical range is that recorded by the manganese steel, while the molybdenum alloys again show only a small amount of expansion. The carbon and the vanadium steels have the highest critical temperatures and the nickel-chromium steel has the lowest.

TABLE V.—*Data on Alloy Cast Steel Bars Restrained by Strong "C" Spring.*

Steel no.	Type.	Per cent. contraction before critical range.	Per cent. expansion passing through critical range.	Per cent. contraction after critical range.	Per cent. total contraction.
1	C ..	0.20	0.15	0.42	0.47
2	High Mn	0.28	0.22	0.39	0.46
3	Ni ..	0.24	0.18	0.35	0.40
4	Cr ..	0.21	0.17	0.43	0.47
5	Cu ..	0.25	0.17	0.41	0.48
6	Mo ..	0.31	0.12	0.30	0.49
7	V ..	0.21	0.12	0.35	0.44
8	Mn-Si ..	0.24	0.16	0.35	0.43
9	Ni-Mn ..	0.23	0.18	0.38	0.44
10	Mn-Mo ..	0.26	0.09	0.28	0.45
11	Mn-V ..	0.24	0.16	0.45	0.53
12	Ni-Cr ..	0.37	0.17	0.17	0.37

The variations between the upper and lower contraction curves result in differences in stress varying from 300 lbs. per sq. in. at 1,300 deg. C. to 500 lbs. per sq. in. at 1,000 deg. C. At temperatures above 1,300 deg. C. the curves representing the contraction of the various steels cross each other and change positions so frequently that little can be said definitely about them except that the rates of contraction of the various alloy steels differ considerably. In general, it can be said that at any one temperature the nickel-manganese steel contracts the least prior to the critical range, while the manganese-molybdenum and the molybdenum steels contract the most. This condition is likewise true at temperatures below the critical range. The variations between the curves at temperature below the critical are over twice as great as those before the critical range is reached. The three nickel alloys exhibited the least amount of total hindered contraction.

Heavy Hindered Contraction ("C" Spring).—The tensions exerted by the strong "*C*" spring are probably greater than any encountered in commercial practice, but the data indicate how these unusually high stresses would affect contraction. The data obtained by hindering the contraction of the bar with the heavy "*C*" spring are tabulated in Tables V and VI. The total contraction varies from 0.37 per cent. for the nickel-chromium steel to 0.53 per cent. attained by the manganese-vanadium steel, the carbon steel contracting 0.47 per cent.

In general, the critical temperatures are slightly above those found in the freely contracting bar. The general condition that the lower the temperature at which the critical range occurs, the greater will be the amount of contraction prior to the critical range, again exists. Thus, the nickel-chromium steel again leads by attaining 0.37 per cent. contraction before the critical range is reached. The carbon steel shows the smallest percentage of contraction. The chromium and carbon steels have the greatest amount of contraction after the critical range, whereas the nickel-chromium steel contracts very little, in fact, only an amount equal to the expansion that took place when the steel passed through the critical range.

The manganese steel exhibited considerable expansion during the critical range and, under this heavy spring, the molybdenum alloys again expanded the least. The variation between the high molybdenum curve and the nickel-manganese curve from 1,400 deg. C. to 1,000 deg. C. is only 0.03 per cent. This is equivalent to a difference in stress of about 650 lbs. per sq. in. The curves representing the different alloys cross each other to such an extent that it is nearly impossible to point to any one alloy and to make predictions as to its ability to resist high contraction stresses.

The rate at which contraction takes places changes distinctly in two places. The curves flatten out between 1,350 deg. C. and 1,200 deg. C. and then, around 1,000 deg. C. to 950 deg. C., there is a decided upward bend in the curves. At the lower temperatures, certain alloys show an appreciable drop in the rate of contraction, while other alloys have very little reduction in their rates of contraction. The decrease in the rate of contraction is most noticeable with the nickel-manganese and the manganese-vanadium steels. The rates for the nickel, the vanadium, and the manganese-silicon steels also fall off appreciably. The low final position of the nickel-chromium steel is probably due to its low critical temperature. All of the other steels are closely grouped except the manganese-vanadium steel, which has a high end point due to its constant rate of contraction.

The effect of resistance upon contraction is illustrated in Fig. 1. The data shown are representative curves and were calculated from the average contraction of the bars at temperature intervals of 50 deg. C. It should be noted that, in the freely contracting bars, the rate of contraction increased uniformly from the solidifying temperature to about 1,200 deg. C. From 1,200 deg. C. to the critical temperature, the rate of contraction is practically constant.

TABLE VI.—*Critical Points of Alloy Cast Steels on Cooling from Solidifying Temperatures, in Deg. C., with Various Hindered Contractions.*

Steel no.	Type.	Critical points.							
		Higher.				Lower.			
		Free.	Spring *E*.	Spring *G*.	Spring *C*.	Free.	Spring *E*.	Spring *G*.	Spring *C*.
1	V	690	685	685	690	620	600	595	595
2	C	690	660	690	675	635	570	615	595
3	Cr	670	680	680	680	615	640	645	630
4	Mn-Si	650	645	655	640	620	620	630	585
5	Cu	645	660	685	670	605	600	600	600
6	Mn-V	640	660	655	650	605	605	610	565
7	Ni-Mn	610	595	635	600	560	550	550	525
8	Ni	600	620	610	615	545	550	550	540
9	Mn	580	605	605	605	510	525	555	535
10	Mo	565	575	580	590	530	450	445	470
11	Mn-Mo	550	550	590	580	470	440	460	450
12	Ni-Cr	430	415	460	440	320	270	280	280

The bars which were restrained in contraction by the heavy "*C*" spring had an entirely different rate of contraction. In this case, the bar apparently yielded at the higher temperatures. The strength of the steel apparently increased slowly with the drop in temperature, since the amount of yielding is decreasing slowly as the temperature drops until at approximately 1,200 deg. C., the strength is sufficient to cause an increase in the rate of contraction. Again at 1,000 deg. C. the rate of contraction increases markedly.

Discussion of the Practical Features Exhibited by the Data

The total amounts of free contraction of the common types of low alloy cast steels are about the same, or slightly less than that of a plain carbon steel of the corresponding carbon content. This point, however, is not of great practical importance, since steel castings are seldom, if ever, in such a form as to allow them to contract freely. Thus a more practical viewpoint would be obtained by considering the characteristics of hindered contraction. The light "*E*" spring produces stresses approximately the same as those encountered by the average commercial casting. Under these conditions, the amounts of total contraction for the alloy steels vary from 1.58 per cent. (practically $\frac{3}{16}$ in. per ft.) to 1.78 per cent. (nearly $\frac{7}{32}$ in. per ft.). The carbon steel, which was used as a standard, contracts 1.64 per cent. (nearly $\frac{13}{64}$ in. per ft.), occupies a position that is intermediate to the alloy steels ($\pm \frac{1}{64}$ in. per ft.). It thus appears that for all practical purposes the carbon steel and the alloy steels studied are similar. This condition holds true only as long as the percentage total contraction is considered. The rates of contraction, the position of the critical points, and the expansion during the critical range may or may not be similar to the characteristics exhibited by a plain carbon steel.

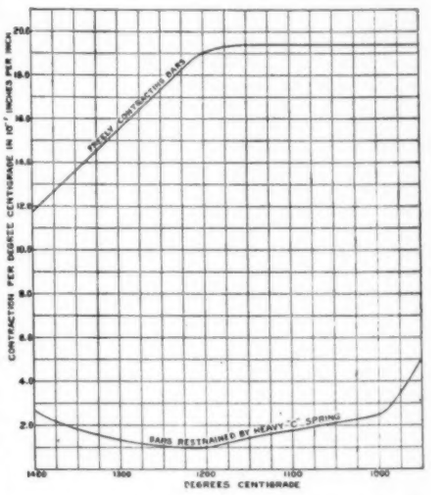
CONTRACTION PER DEGREE CENTIGRADE IN 10" INCHES PER INCH
FREELY CONTRACTING BARS
BARS RESTRAINED BY HEAVY "C" SPRING
DEGREES CENTIGRADE

FIG. 1.—EFFECT OF HEAVY SPRING ON RATE OF CONTRACTION.

The statements given above concerning the hindered contraction under the light "*E*" spring are also true when more drastic conditions of hindered contraction are applied, such as those presented by the "*G*" and "*C*" springs.

It has been pointed out that, at any one temperature, there is a variation in the amount of

contraction of the alloy steels. Although the difference between the steels contracting the fastest and those contracting the slowest is not great, important stress differences are recorded under hindered contraction at higher temperatures. For example, under the heavy "*C*" spring at 1,300 deg. C., the vanadium steel bar is under a stress of 900 lb. per sq. in. at its smallest section, while the nickel-manganese steel has only a stress of 420 lb. per sq. in. acting upon it. Thus, at these high temperatures under large amounts of hindered contraction, the vanadium steel is subject to over twice the amount of stress that is acting on the nickel-manganese steel. Furthermore, it is not until a temperature of 1,100 deg. C. is reached that the nickel-chromium steel must withstand the same stress as that to which the vanadium steel is submitted at 1,300 deg. C.

The condition stated above has no bearing on the ultimate strength of the steel, however, except that it shows that the slower contracting steel may have a lower yield strength at the higher temperatures. This was pointed out when it was explained that the bars in contracting could only develop a stress equal to their yield strength. When the yield strength was exceeded, the steel yielded, thus causing a relieving of the stress. Upon further contraction of the steel, the stress is again built up to the yield strength. Thus the vanadium steel apparently has, at 1,300 deg. C., about twice the yield strength of a nickel-manganese steel. This is important from a practical standpoint for it gives an indication of the yield strengths of the alloy steels when contraction has been hindered at high temperatures.

The apparent yield strengths, and not the true yield strengths, of the steels are recorded as the stresses upon the bars at any one temperature vary considerably with the type of contraction. For example, the vanadium steel at 1,300 deg. C. has contracted 0.064 per cent. when restrained by the "*G*" spring and only 0.044 per cent. when restrained by the heavier "*C*" spring. The bars, therefore, are under a stress of 465 lbs. per sq. in. when the "*G*" spring is used and under a stress of 920 lbs. per sq. in. when the "*C*" spring is used. As the bars cannot maintain a stress greater than their yield strength, the values given above are the apparent yield strengths of the material under these two conditions. The only difference in the conditions when these two springs are used, is the rate at which the stress is applied. The true yield strength would be indicated only if the stresses were applied at such a rate that no contraction would take place. Under these conditions the stresses on the bars would be equivalent to the true yield strengths of the steels.

The apparent yield strength is recorded only under conditions of hindered contraction which produce rate of contraction-time curves similar to that shown in Fig. 1, and then only at those temperatures at which the curves have a negative slope, in other words, at those temperatures at which the rate of contraction is decreasing. A curve showing the average rate of contraction with the medium "*G*" spring has the same trend as that of the curve for the rate of contraction with the heavy "*C*" spring (Fig. 1). However, the contraction data recorded when the light "*E*" spring was used produced a curve of a different type which exhibited no decrease in the rate of contraction at the higher temperatures. Under these conditions, it appears that the apparent yield strength is not reached even at the higher temperatures, and that only the plastic flow of the metal is recorded.

Summary

The data presented may be summarised as follows:—

(*a*) The free contraction of a plain 0.35 per cent. carbon steel is greater than that of any of the alloy steels studied. The total percentage of free contraction varies from 2.27 per cent., attained by the nickel-chromium steel, to 2.40 per cent., recorded by the nickel steel.

(*b*) The amount of contraction taking place in both freely contracting and hindered contracting bars prior to reaching the critical range is, in general, dependent upon the temperature at which the critical range occurs.

(*c*) The total amount of hindered contraction obtained corresponds closely to that exhibited by the plain carbon steel. The relative final positions of the different alloys vary somewhat with different amounts of tension on the bars.

(*d*) The amount of expansion shown by the alloys during the critical range varied considerably. In general, the amount of expansion under hindered contraction is greater than that recorded with freely contracting bars.

(*e*) Differences in the pouring temperature of the steel have no effect upon the total amount of contraction in the solid state or upon the shape of the contraction curve.

Acknowledgment

The authors wish to express their appreciation to various members of the Naval Research Laboratory for their ready co-operation in the research problem; Mr. James Darby and Mr. Roy Donaldson for their aid in all phases of the test procedure, and Mr. Tom Cunningham for his indispensable foundry abilities and Mr. Louis Singer for chemical analyses.

Wear Resistance of Metals

The Annual Report of the National Physical Laboratory for 1935,* recently published, states that during the past year further attention has been given to the investigation of the phenomenon of "wear oxidation." This process consists in the oxidation of the surfaces of the test specimens and the subsequent rubbing off of oxide *débris*, the process being a continuous one. It occurs under conditions of rolling abrasion, where the surfaces of two steel specimens roll together, but have a slight relative velocity. Many attempts have been made to obtain an atmosphere in which wear oxidation does not occur. These have not been successful, and it appears that a special technique is required to reduce the oxygen content to a value low enough to produce the desired phenomenon.

A number of other tests, on specimens cut from locomotive tyres, indicate that results obtained in the abrasion machine are a guide to the behaviour of the material in actual use. It is found that if two materials of slightly different wear-resisting qualities, as indicated by behaviour in service, are tested together in the machine, the loss of weight by wear of the specimen from the inferior material is two to three times greater than the loss of weight of the specimen from the better material.

Experiments are also being carried out on "mechanical abrasion," in which the material is worn from the test specimens in metallic form under normal atmospheric conditions. This abrasion is produced by running the cylindrical specimens in the same direction, so that at the line of contact the surfaces are moving with equal velocities in opposite directions. A series of tests carried out on mild-steel specimens of 1¾ in. dia., running at a speed of 60 r.p.m. and with contact loads of 10, 20, 30 and 40 lbs., showed the amount of wear to be nearly proportional to the load. At contact loads below 10 lbs. the results were erratic, and the approximate relationship between wear and load does not hold.

* H.M. Stationery Office, Adastral House, Kingsway, London, W.C.2. (Price 12s.)

Progress in Welding

ARC AND OXY-ACETYLENE

At the annual general meeting of the Institute of Welding held in London recently, SIR ALEXANDER GIBB, G.B.E., F.R.S., in the course of his presidential address, referred to a number of important building projects in which welding had played a prominent part, including the steelwork of the Bank of England completed a few months ago; the new entertainment hall at Bexhill, which at the present moment is the largest all-welded building constructed in this country; an all-welded power and turbo-blower house at the Clyde Iron Works; a section of an eight-storey block of 940 flats at Leeds. He also referred to the progress of welding in the shipbuilding industry; all-welded barges, trawlers and tankers, he remarked, had been constructed during the past year, and, of these, the "Franquelin"—a tanker built by Messrs. Swan, Hunter & Wigham Richardson, Limited, for Canadian owners—was the largest all-welded ship built in this country to date. At the same time, in addition to the general increase in partial-welded construction, special application had also shown a marked increase, for instance the use of welded joints to obtain flush decks on liners; to ensure gas tightness on fruit ships and refrigerated carriers; to preclude leakage in oil and water tanks on all classes of ships; and in seatings to minimise vibration. The ships in course of construction for the British and foreign Admiralties showed a still greater advance in welding, class by class. The destroyers and cruisers, consisting of both mild and alloy steel, galvanised and black, had a large proportion of their structures welded, inclusive of recent cruisers with a proportion of welded shell.

Continuing, the speaker said that the use of electric-arc welding for the purpose of fabrication had been gradually increased by the British railways. Notable examples of welding included the carriage underframes constructed for the "Silver Jubilee" train by the London & North Eastern Railway, the construction of first-class sleeping cars built for the London Midland & Scottish Railway at their Wolverton Works, and the building of a number of special wagons, 68 ft. long, for the London Passenger Transport Board, for the purpose of transporting rails up to 61-ft. lengths, sleepers, chairs, ballast and other articles necessary for the construction of new extensions to the system. In various directions there had been much progress made in the application of welding to heavy machinery.

After referring to the progress in welding of non-ferrous metals, both by the arc and oxy-acetylene processes, Sir Alexander remarked, in connection with the latter, that mention must be made of the important work done by the British Acetylene Association in welding education and research, both as industrial corporate members of the Institute and in the industrial field; particularly by making itself responsible during the present year for the promotion of the 12th International Congress of Oxy-Acetylene Welding. They still only stood on the threshold of an era of engineering development in which welding might well prove to be the greatest factor in the development of new methods and new technique in all forms of construction.

Blast-Furnace Gas for Clyde Steelworks

The first adaptation of blast-furnace gas to steel works' use in Scotland will be carried through when arrangements are completed for taking gas from the Clyde Ironworks, Tolcross, of Colvilles, Limited, to the same company's Clydebridge Steelworks, Cambuslang. The gas main will have to cross the River Clyde.

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Leaves from a Foundryman's Notebook

XII.—SPLITTING LOAM CASTINGS

By "RECORDER"

Circular castings, such as drumsides, etc., that are frequently made in loam moulds by sweeping boards, are usually required in halves to facilitate erection of the job, especially if repairs and renewals are to be effected without taking the whole winding engine to pieces. There are three methods by which this can be accomplished. The first is by inserting a piece of ¼ in. plate in the mould between the arms that are subsequently to be bolted together, thus separating the two castings. The second method is by inserting a thin core with a number of holes in, so that the metal between the two halves is connected at various places when cast. Again, the third, and probably the best, method is to strike up two halves of a mould by an eccentric spindle, which allows of a space of 3 in. between them. Into this space a core can be placed, of a thickness that will permit of the finished castings being machined on the joint if so desired.

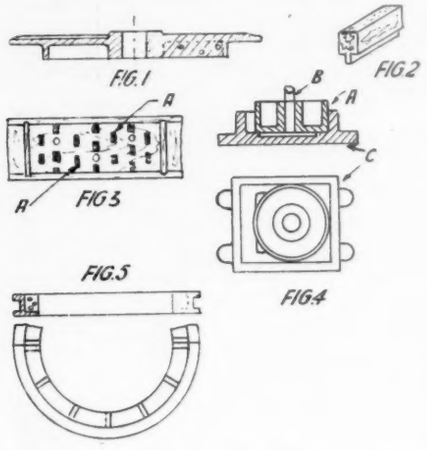


Fig. 1 is a section of a drumside for a haulage engine such as was considered in the second article of this series. The sweeping boards required to make this job are identical with those then described, the only difference being in the pattern work which is introduced in the mould during the process of building. If the first of the methods to accomplish the manufacture of the job in two pieces is decided upon, in place of two of the ribs, two others of twice that thickness, plus ¼ in. for a print, will be required (Fig. 2).

The job will then be built as previously, and on assembly a piece of ¼ in. thick iron plate of a suitable contour will be introduced into these prints, and thus separate the two portions of the drumside. If the second method was used, the pattern work would be similar, but in place of a ¼ in. iron plate a ¼ in. core produced in a box as shown in Fig. 3 would be required. A-A in Fig. 3 are pieces of wood, which in the casting become pieces of metal joining the two halves of the job together. After fettling, the casting is finished machined in the bore and on the rim and then split by driving wedges in the opening left by the ¼ in. core.

The third method of manufacture is by means of an eccentric spindle. This method consists in striking up half a mould and then sliding the spindle over 3 in. and repeating the operation. To allow of this, a special rig is required in which the footstep slides, this being shown in Fig. 4. The footstep A carrying the spindle B is identical in design to those used previously, instead, however, of its being weighted in one position, it is placed within a sole-plate C, the interior of which is 3 in. longer than the outside diameter of the footstep.

The pattern work required for this method is the same as before, only in place of the two separate arms, each carrying a ¼ in. print, now one long print extends the full width of the job, carrying portions of the required arms on each side. This print is 2¼ or 2½ in. thick, depending on the amount of machining allowance required on the arms of each half. This core goes the complete length of the print, and in place of the centre core, which in the two previous methods could be used as a complete diameter, two are now required—the amount of the machining on the arms more than half round.

An interesting example of a circular casting required in halves is shown in Fig. 5; it is a brake race for a haulage engine, and was required to be bolted against the side of an existing drum. As this casting was not connected to a central boss by any arms, etc., it was considered rather a risky job casting it in two pieces, for fear of distortion, as jobs such as this—open one end—have a tendency to distort and "go big" across the diameter. On this particular example a machined joint was called for, making it impossible to manufacture it by the second method, already described in connection with the drumsides.

Both casting in two separate halves, on account of anticipated distortion, and "splitting cores" because of the necessity to machine the joint being ruled out, it was decided to cast the job as a complete ring. This ring was made larger across one diameter than the other, with the extra thickness allowed on the lugs used for bolting the finished job together. The mould was swept up in loam by means of an eccentric spindle, as in the third method, but no core separated the two pieces. The casting was cut in two by a large circular saw and the joint planed; the two halves were then bolted together and machined on the rim, and the job was satisfactory in every respect.

Publications Received

Monel Metal. A folder, received from Henry Wiggin & Company, Limited, Thames House, Millbank, London, S.W.1, is mainly composed of illustrations of the application of Monel Metal in architectural work in America. A very high standard of artistic merit is shown, both when used in either modernistic or traditional style. A folder of this character is very useful on account of the suggestions it reveals for the treatment of new constructions on this side of the Atlantic.

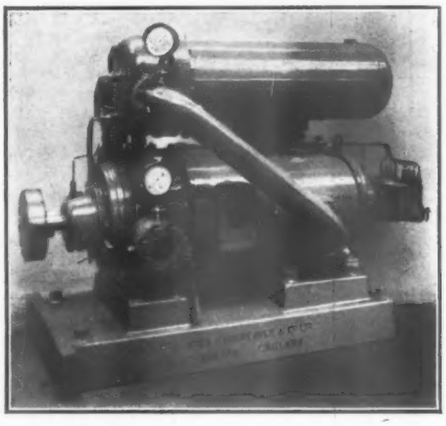
"Staybrite" Steel. Firth-Vickers Stainless Steel, Limited, of Staybrite Works, Sheffield, 9, have sent us a copy of a 32-page booklet, the object of which is to familiarise the public with the wide range of household articles which are now available in "Staybrite" steel. There is little text in the booklet, apart from a brief outline of the properties of the material, but there are something like 150 illustrations of articles fabricated from "Staybrite" steel. These are grouped together under such headings as "By the Fireside," "For the Smoker," "For the Kitchen," "On Your Table," "For Your Personal Use" and so on, and support the statement that almost any article in this particular metal can now be obtained.

Rotary Air Compressors

IMPROVED MULTI-CELLULAR DESIGN

During recent years the high-speed rotary air compressor has made great strides, particularly because of the small size and convenience of driving by a direct-coupled electric motor. In this connection considerable interest attaches to the latest designs of rotary air (or gas) compressors made by Hick, Hargreaves & Company, Limited, of Bolton, which have a number of notable features, such as a series of fully-floating restraining rings, roller bearings, and enclosed casing, and available also for portable or inbye use. The general construction of these compressors will probably be familiar to our readers, but certain improvements have recently been effected.

The design, it will be recalled, is of the positive, multi-chamber, rotary type, consisting of a cast-iron rotor carried on a spindle, running eccentrically at high speed in an outer steel cylinder or casing. Also, the rotor has a number of loose steel blades carried in a series of deep radial slots, these blades being thrown outwards by the centrifugal force so that they always make airtight connection with the inside of the outer cylinder, irrespective of their position, in relation to the space formed at one portion between the cylinder and the rotor, due to the eccentric mounting of the latter.



HICK, HARGREAVES ENCLOSED-TYPE TWO-STAGE AIR COMPRESSOR.

The tips of the blades, however, do not come into actual contact with the cylinder, but with the floating restraining rings, which are of very slightly less internal bore than the cylinder, these rings also revolving at a high speed, practically the same as the rotor, so as to reduce the friction to a minimum. The cylinder is provided with air suction and discharge ports situated in such a position that the air (or gas) is compressed gradually and uniformly as it is carried through by the blades projecting radially from the rotor, always at the correct length to ensure efficient contact with the restraining rings. The standard sizes are within the range of 8 to 2,700 cub. ft. of free air per min., and in twin machines double the capacity, with air pressures of, say, 1 to 150 lbs. per sq. in. (or 99.5 per cent. vacuum if worked as a vacuum pump).

Long Blast-Furnace Campaign

For the second time in the history of the blast-furnace department of the Ilseder Hütte, Peine, a blast furnace has reached an aggregate output of 1,000,000 tons of pig-iron. The furnace in question has been operating for eight years and has just turned out its millionth ton of pig-iron.

The supplying of vitreous acid resisting enamels is a problem which has been tackled by our experts, who have studied the difficulties incurred by the usage of these enamels and have reduced them to a minimum.

Our Associated Company JAMES DAVIES (LONGTON), LTD., Ceramic Transfers, Berry Bank, Stafford Street, LONGTON, Stoke-on-Trent
('Phone: 3343 'Grams: "Ceramic, Longton, Stoke-on-Trent),
will be pleased to supply suitable vitreous transfers.

N. SINCLAIR & CO. LTD.

CLYDE COLOUR & CHEMICAL WORKS, NILE STREET, BURSLEM, STOKE-ON-TRENT.
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The Week's News in Brief

Trade Talk

EDGAR ALLEN & COMPANY, LIMITED, have recently completed some important trackwork layouts, one of which, for the Stockholm tramways, weighs about 125 tons.

FALKIRK DEAN OF GUILD COURT have approved plans for the erection of a new blacking shop at Sunnyside Iron Works for the Forth & Clyde & Sunnyside Iron Company, Limited.

ABOUT THIRTY MEMBERS of the Derby Society of Engineers visited the L.M.S. research laboratories at Derby last week, by invitation of Sir Harold Hartley, a Vice-President of the L.M.S. and director of scientific research.

THE ABERDEEN BRANCH of the National Union of Foundry Workers has instructed all members to refuse to work overtime until the employers agree to pay the standard rate for Scotland. Negotiations have failed to secure an agreement to observe the national rate.

RAIN-WATER AND SOIL PIPES with melt-on patent ears have made rapid progress since their first introduction. The number of pipes of this type sold during the quarter ended March 31 is announced as 168,579. The total for the previous quarter was 164,274 and for the quarter ended September 30, 1935, 150,638.

PREPARATIONS are being made for reopening the Wallace Foundry in Brown Constable Street, Dundee. The Wallace Foundry was opened in 1856 by Urquhart, Lindsay & Robertson Orchar, Limited, and by 1906 the firm had a world-wide reputation as textile engineers. In 1921 the business became amalgamated with Fairbairn, Lawson, Combe Barbour, Limited, of Leeds.

THE PIG-IRON OUTPUT of Czecho-Slovakia in April was 89,486 tons compared with 89,732 tons in the preceding month, and with only 56,600 tons in April, 1935. The first four months of the current year have registered an output of 352,000 tons as against only 239,000 tons in the corresponding period of 1935. Steel production in April was 125,975 tons, compared with 120,838 tons in March, and with 93,600 tons in April, 1935. The total output of steel for the first four months of this year is approximately 462,000 tons, compared with 374,000 tons in the like period of 1935.

AFTER TWELVE YEARS at Baldwin Terrace, Wharf Road, Islington, E. H. Jones (Machine Tools), Limited, are shortly moving to larger premises at Hendon. The firm has purchased the freehold of the Studebaker depôt of Henlys, Limited, close to Hendon Aerodrome, and a few minutes from Colindale Tube Station. The new premises, standing in an acre of ground, have a floor area of 40,000 sq. ft., and this additional space will enable the firm to maintain its policy of carrying in stock machine tools of every description, in order to give prompt deliveries. Change-over to the new premises will commence shortly and is expected to be complete by August 15.

AT THE 45th annual meeting of the American Iron and Steel Institute, in New York, there was a consensus of opinion that, while the United States steel industry faced many problems, including high costs, and was hampered by various political interferences, the country, slowly but surely, was working its way out of the depression. The steel industry was enjoying the best outlook at this time of the year for six years. Mr. William A. Irvin, President of the United States Steel Corporation, said that accumulated requirements for steel for replacements and repairs were beginning to manifest themselves in orders which should keep steel plants fairly active for some time. The steel industry, as a whole, was now operating at 86 per cent. of capacity, as against the 55 per cent. average for the first quarter of 1936. Mr. Eugene C. Grace, President of the Bethlehem Steel Corporation and of the American Iron and Steel Institute, in opening the meeting, said that the steel industry was now employing 450,000 persons, or as many as at the height of the prosperity of 1929. Mr. Grace was re-elected President of the Institute.

DURING A DISCUSSION in the Irish Free State Legislature last week on the Budget resolution imposing a duty of 40 per cent. on various types of cast-iron building and household goods, the Minister for Industry and Commerce was asked why such a proposal had to be brought in, as the majority of these goods were already subject to duty. The Minister, in reply, said that there was no reason why cast-iron goods should have to be imported, except articles of a particular kind. It was the intention of the Government to develop the Free State foundries and as one step in that direction they had required the Housing Board to ensure that in the houses subsidised by the Government only Free State manufactured cast-iron goods would be used. In 1935 £300,000 worth of cast-iron goods were imported. Until the Free State firms were in a position fully to supply the market a licensing system would be introduced. This system would allow people whose requirements could not be met by home foundries to import free of duty. He anticipated that it would require five hundred additional men to supply the country's requirements. There were several foundries in operation and that there was considerable competition was shown by the keen prices quoted for contracts. The resolution was passed.

Company Reports

Harland & Wolff, Limited.—Profit on trading, before depreciation, £42,934; interest received, £1,090; brought in, £50,054; carried forward, £117,873.

John Dale Metal Containers, Limited.—Net trading profit, after providing for depreciation, £13,559; rents and interest receivable, £1,111; reserve for income tax, £2,300; dividend on the 5½ per cent. cumulative preference shares for the year ended October 31, 1935, £4,125; managing directors' commission on profits, £989; interim dividend of 2½ per cent. on the ordinary shares, £1,875; brought in, £5,875; final ordinary dividend of 3 per cent., £2,250; carried forward, £8,355.

Guest, Keen & Nettlefolds, Limited.—Preliminary statement shows that after charging debenture interest amounting to £66,262, and making provision out of profits for redemption of debenture stock amounting to £36,012, the profits of the year ended March 31 are approximately £940,000. Final dividends on the first preference stock, second preference stock and on the ordinary stock, all at the rate of 2½ per cent., free of tax, making dividends of 5 per cent., free of tax, for the year in all cases are recommended.

Contracts Open

Johannesburg, July 6.—Steelwork, for the South African Railways and Harbours Administration. The Chief Store Superintendent, Park Station Chambers, Rissik Street, Johannesburg.

Preston, June 30.—7,655 yds. of 38-in. dia. cast-iron pipes, for the Town Council. The Borough Engineer, Municipal Building. (Fee £3 3s., returnable.)

Wellington, July 7.—Two electric, motor-driven, low-head centrifugal pumps, with equipment, for the New Zealand Public Works Department. The Department of Overseas Trade. (Reference T.Y. 30.282.)

Company Meeting

Presiding at the annual meeting of Walter Somers, Limited, held at Haywood Forge, Halesowen, on May 27, MR. S. S. SOMERS said he was glad to be able to report that the condition of the forging trade had so far improved that their year's trading had resulted in a profit for the first time for many years. The company has gone through a very difficult time for the past fifteen years; the demand for their manufactures had been so small that it had been impossible to keep more than a small proportion of the plant employed. Although the existing plant had been maintained in excellent condition, it was very necessary that further plant to deal with particular classes of manufactures should be purchased, and for this reason a higher rate of dividend was not recommended. Work turned out during the past year had been approximately 50 per cent. higher than the average of the past 14 years, and this improved rate of output was at present continuing.

Personal

MR. J. G. PEARCE (director and secretary of the British Cast Iron Research Association) has changed his address to 17, Abbey Road, Harborne, Birmingham, 17. His new telephone number is Harborne 2163.

MR. J. PERCY PLANT, retiring chairman of the management committee of the Engineering and Hardware Section of the British Industries Fair, was re-appointed chairman for the third year in succession, at a meeting of the Birmingham Chamber of Commerce on Monday.

MR. C. E. SIMS has been appointed research metallurgist at the Battelle Memorial Institute, Columbus, Ohio. Mr. Sims served for some years as metallurgist in the U.S. Bureau of Mines, and in 1927 joined the American Steel Foundries, Indiana Harbour, Indiana, as assistant director of research.

MR. THOMAS SHANKS, works manager of the Denny Iron Works of Cruikshank & Company, Limited, and elder son of Ex-Provost J. K. Shanks, M.B.E., J.P. (managing director), was presented last week with an H.M.V. refrigerator as a gift from the directors and employees on the occasion of his marriage to Miss Isobel Dewar, of Craigdhu, Stirling. Mr. Alex. Hay, foreman of the malleable and steel department, presided.

MR. ARNOLD CARR, manager of the foundry supplies department of Thos. W. Ward, Limited, of Albion Works, Sheffield, has received some very pleasing and spontaneous expressions of congratulation upon his recently-reported elevation to the local directorate of Messrs. Ward. He has been presented, on behalf of his staff, with a silver cigarette case, suitably engraved. On May 22, a number of his business friends organised a luncheon in his honour, at the King's Head Hotel, Sheffield. At this luncheon several of his hosts, some of whom had travelled considerable distances to attend the function, spoke of the very pleasant relationships that had always marked their business dealings with their guest and of the esteem in which they held him as a personal friend. Mr. Carr will be well remembered by foundrymen in London and the Eastern Counties, as for a period of about six years he managed the London section of the foundry trade of Thos. W. Ward, operating from Silvertown Works. This side of the business is still controlled by Mr. Carr under the management of Mr. R. Causebrooke, who was trained by Mr. Carr during his stay in London.

MR. ARNOLD CARR.

Obituary

THE DEATH has occurred, at the age of 83 years, of Mr. Henry Warren, senior partner in the firm of Warren Brothers, boilermakers and engineers, of Newhall.

THE DEATH occurred at Darlington last week of Sir Thomas Putnam, formerly managing director of the Darlington Forge, Limited. Sir Thomas, who was born at Darlington 74 years ago, joined the Darlington Forge at the time when it belonged to his father, the business subsequently being converted into a limited liability company. When the forge was taken over by the English Steel Corporation, Sir Thomas was invited to join the board of directors, but declined.

Forthcoming Events

JUNE 8-13.

Twelfth International Congress of Acetylene, Oxy-Acetylene Welding and Allied Industries:—To be held in London, at Caxton Hall, Westminster.

Institute of British Foundrymen

JUNE 9-12.

Annual Conference in Scotland.

ROWLAND

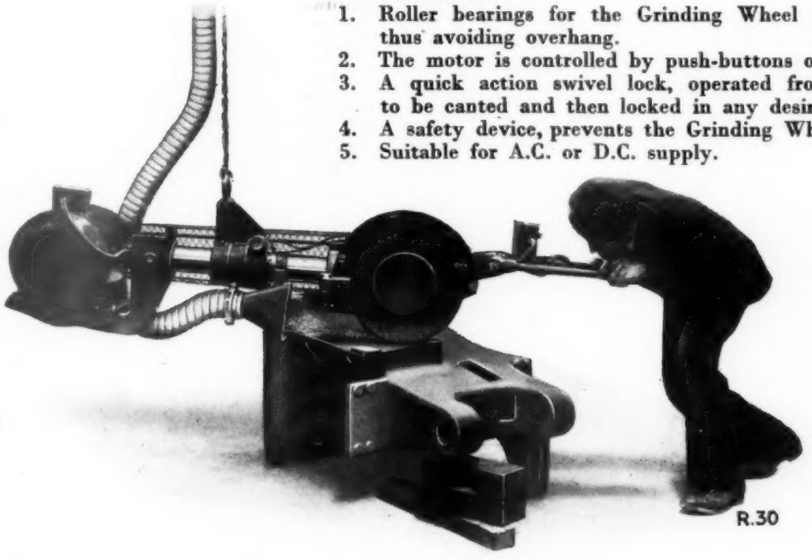
HIGH SPEED PORTABLE GRINDER

This is an entirely new High Speed Grinder, for fettling castings which cannot be handled.

It is quick and light to operate, yet sturdy, of build.

Exclusive features:

1. Roller bearings for the Grinding Wheel are located inside the Wheel collet, thus avoiding overhang.
2. The motor is controlled by push-buttons on the handle-bars.
3. A quick action swivel lock, operated from the handle-bars enables the Wheel to be canted and then locked in any desired setting.
4. A safety device, prevents the Grinding Wheel being run at an incorrect speed.
5. Suitable for A.C. or D.C. supply.



All foundries should have particulars of this new machine.

F. E. ROWLAND & CO., LTD., Climax Works, REDDISH, STOCKPORT

LONDON: H. C. Amos & Co., 22, Martin Lane, Cannon Street, LONDON, E.C.4
N.E. Coast: T. Feather, Esq., 16, Devonshire Place, Jesmond, NEWCASTLE-on-TYNE.
MIDLANDS: L. Williams, Esq., 31, Parkside, COVENTRY.
SCOTLAND: Wilson Feather & Son, 122, Wellington Street, GLASGOW.

WARNER Special PIG IRONS

- Warner C.B.R.
and
- Low Carbon Cylinder
(FOR CYLINDERS, ROLLS, ENGINEERING CASTINGS, ETC.)
- Low Carbon Malleable
(FOR MALLEABLE CASTINGS OF ALL DESCRIPTIONS)

Supplied to any specification between limits of 2·00 and 3·50% Carbon and ·50% and 3·50% Silicon

ACTUAL ANALYSIS CERTIFICATES ARE AVAILABLE WITH EACH DELIVERY

Typical Cylinder Pig Iron Specification

TOTAL CARBON	2·70%
SILICON	1·80%
MANGANESE	·90%
SULPHUR	·06%
PHOSPHORUS	·40%

Typical Malleable Pig Iron Specification

TOTAL CARBON	2·60%
SILICON	·75%
MANGANESE	·50%
SULPHUR	·05%
PHOSPHORUS	·06%

WARNER & CO., LTD
MIDDLESBROUGH

Raw Material Markets

Business in the iron and steel trades has been fully resumed following the Whitsuntide recess, but it is not possible, as yet, to gauge the effect of the recent advances in prices. Makers will not receive the benefit of these increases for several months, for they are well sold under the old quotations. It is generally anticipated that new business will be transacted more freely in the near future. Makers' outputs at the present time are creating new records.

Pig-Iron

MIDDLESBROUGH.—There has been a large number of inquiries circulating on the Cleveland pig-iron market and the works continue to be well employed. The delivery position has been slightly relieved by the stoppage of work at the consuming plants during the Whitsuntide vacation. Supplies from the Midlands are being taken up by users in this area on a heavy scale. Export business has been completely suspended. Prices are based on No. 3 Cleveland G.M.B. at 75s. per ton in the Middlesbrough and Falkirk areas, 77s. on the North-East Coast, and 78s. in Glasgow.

Makers of East Coast hematite have been able to comply with their commitments, but there is little surplus and business over the next few months is difficult to transact. The rise in quotations of 3s. 6d. per ton was less by 1s. 6d. than many makers had expected and hoped. No. 1 East Coast material is now quoted at 80s. 6d. per ton in Scotland, Northumberland, Durham and North Yorkshire.

LANCASHIRE.—Trading conditions have been quieter in this area since the holidays and deliveries have been adversely affected by the closing of the works. West Coast hematite is now quoted at about 88s. 6d. per ton, delivered equal to Manchester, while East Coast iron is quoted at about 6d. per ton less. Offers of Derbyshire, Staffordshire and Lancashire brands of No. 3 foundry iron equal to Derbyshire, for delivery to users in the Lancashire price zone, are all on the basis of 78s. per ton, with Northants at 76s. 6d. There is no change in the quotation for Scottish No. 3 at around 89s. per ton, including delivery equal to Manchester.

MIDLANDS.—Conditions in this area are very satisfactory, the deliveries during May amounting to a substantial tonnage. It is expected that this month's deliveries will also be on a high scale, for many consumers have contracts at current prices up to the end of the month, after which they will pay the 5s. per ton increase. Quotations, including delivery to Birmingham and Black Country stations and subject to the July 1 advance, are 75s. per ton for Derbyshire, Lincolnshire and North Staffordshire No. 3, and 72s. 6d. for Northamptonshire No. 3, less a small sliding-scale rebate to large consumers. The revised prices of hematite iron delivered Birmingham and Black Country stations in 10-ton lots are £4 12s. for West Coast mixed numbers, £4 11s. for East Coast No. 3, and £4 10s. 6d. for Welsh mixed numbers, with 1s. 6d. per ton extra if delivered into works. It is exceedingly difficult to obtain deliveries of forge pig-iron, which is very scarce. The price is 5s. per ton below that of No. 3 foundry if used for puddling, but only 3s. less if required for foundry purposes. The demand for special-quality irons is very satisfactory. Supplies enter the district from several areas and the prices continue to be without control. Low-phosphorus iron is quoted at from 92s. 6d. to 100s., with Scottish at about 95s., medium-phosphorus from 80s. to 87s. 6d., while refined iron is on offer between £6 10s. and £7 15s. per ton, delivered local stations.

SCOTLAND.—Deliveries are on a good scale in the Scottish area. No. 3 foundry is still quoted at 79s. f.o.t. furnaces, with 2s. 6d. extra for No. 1. Light-castings founders are very active and are taking up satisfactory tonnages of iron. Quotations for No. 3 Cleveland iron are nominal at 70s. f.o.t. Falkirk and 73s. f.o.t. Glasgow. Other English foundry irons are 1s. 3d. per ton below the foregoing figures, but a premium has been demanded in some cases. Local steelworks continue to have heavy requirements of pig-iron and their plants are working to capacity. Prices of steel-making irons are 80s. 6d. for mixed numbers of East Coast. West Coast and Scottish hematite, with basic, British and Indian, at 75s. (less 5s. rebate), delivered local steelworks.

Coke

It continues to be very difficult to obtain supplies on the foundry-coke market. Lower prices are usual at this period, but makers indicate that they are more likely to raise prices later on than lower them. For delivery to Birmingham and district best Durham coke is quoted at from 41s. 6d. to 43s., with other grades down to 39s. 6d., while Welsh coke is from 39s. to 50s. per ton.

Steel

The volume of new business in the steel market has been somewhat restricted since the holidays, but a considerable amount of inquiry has been put into circulation, says the official report of the London Iron and Steel Exchange. The manufacturers are acting cautiously in the matter of undertaking new commitments, as they are well sold until late in the year, and the periods required for delivery are gradually lengthening. In the semi-finished steel department the situation has become easier, and there is not the same pressure to obtain supplies. This is the result of an expansion in British production and of the increased quantities of Continental material imported by special arrangement. In the finished steel section of the market heavy deliveries continue to be made to the consuming works, and in most branches the mills are operating at capacity. Some improvement has been noticeable lately in the export trade, but the great bulk of the production represents home requirements.

Scrap

Steelworks in the Cleveland area continue to take good supplies of scrap, in spite of heavy importations from abroad. Heavy melting steel is still officially quoted at 57s. 6d. per ton, but the position is somewhat easier, and this is about the most that is obtainable. Ordinary heavy cast iron is at a minimum of 62s. 6d., while 65s. is quoted for good machinery cast iron, but the demand has decreased. Quiet conditions rule on the South Wales market and little business has been transacted. Heavy steel scrap in furnace sizes is only offered in small tonnages at 60s. to 65s., while bundled steel scrap receives few inquiries at 60s. to 62s. 6d. Good, heavy metal is quiet at 60s. to 61s. 6d. and compressed bundles receive a steady demand at 57s. 6d. Heavy cast-iron scrap, in large pieces and furnace sizes, is firmer and more is changing hands at 58s. to 60s. per ton. Activity has been maintained on the Midlands market. Heavy steel in furnace sizes is at 52s. 6d. to 55s., and mixed heavy iron and steel at 52s. 6d. Short, heavy steel, suitable for foundries, is at 70s. and in short supply. Business continues to be rather slack on the Scottish market, and prices are unchanged. Heavy mild-steel scrap is at 57s. 6d., with basic at 52s. 6d. Heavy machinery cast-iron scrap is quoted around 70s., while ordinary cast iron is at 67s. 6d. per ton, delivered consumers' works.

Metals

Copper.—Although consumption is reported to have been well maintained during the January to March quarter, 1936, at about 60,000 tons, which is an increase of 2,000 tons as compared with the previous quarter, conditions in this market are dull. The statistical position is sound and is improving steadily. Prices have further declined, but it is generally accepted that this metal is worth several pounds more than the current quotation. The market is quiet in the United States and on the Continent.

Daily market prices :—

Cash.—Thursday, £36 to £36 1s. 3d.; Friday, £36 to £36 1s. 3d.; Monday, £36 5s. to £36 6s. 3d.; Tuesday, £36 5s. to £36 6s. 3d.; Wednesday, £36 1s. 3d. to £36 2s. 6d.

Three Months.—Thursday, £36 6s. 3d. to £36 7s. 6d.; Friday, £36 6s. 3d. to £36 7s. 6d.; Monday, £36 11s. 3d. to £36 12s. 6d.; Tuesday, £36 11s. 3d. to £36 12s. 6d.; Wednesday, £36 7s. 6d. to £36 8s. 9d.

Tin.—Prices have recovered some ground, but conditions are still uncertain. The weekly review of the metal markets issued by Rudolf Wolff & Company, states that "the outstanding weakness which the market has displayed must be attributed to the somewhat disquieting reports and rumours with regard to the restriction scheme, attention being drawn to the unsatisfactory position disclosed at the last meeting of the International Tin Committee and the further possibility that the scheme may not be renewed at the end of the year. The situation, furthermore, was aggravated by the less favourable statistics. In the circumstances, the market remains in a very sensitive condition. Consumption is reported to be well maintained at 6,000 tons for the first quarter of this year, and demand on the part of consumers during the week has at times been more active than hitherto."

Metal Exchange quotations were as follow :—

Cash.—Thursday, £183 to £183 10s.; Friday, £187 5s. to £187 15s.; Monday, £187 15s. to £188; Tuesday, £184 10s. to £185; Wednesday, £183 10s. to £183 15s.

Three Months.—Thursday, £181 7s. 6d. to £181 12s. 6d.; Friday, £185 7s. 6d. to £185 12s. 6d.; Monday, £185 12s. 6d. to £185 15s.; Tuesday, £182 5s. to £182 15s.; Wednesday, £181 10s. to £181 15s.

Spelter.—The quotation for this metal declined to the lowest level of this year during the past week. It is difficult to determine with any degree of precision the outlook for spelter. Both monetary and political influences are against any development at the present time. Consumption for the first quarter of 1936 was 49,000 tons, as compared with 54,000 tons in the previous quarter. Quiet conditions have prevailed in the United States, but the price has been maintained, although it is liable to fluctuation.

Official quotations were as follow :—

Ordinary.—Thursday, £14 3s. 9d.; Friday, £14 2s. 6d.; Monday, £14 5s.; Tuesday, £14 2s. 6d.; Wednesday, £14 2s. 6d.

Lead.—New business is very quiet in this market and dull conditions continue to prevail. Consumption during the January to March period of this year was 84,000 tons, a decrease of 1,000 tons as compared with the previous three months. Deliveries of pipes and sheets are heavy, while cable, accumulator, and oxide makers are active. The world's output in March was 117,068 tons, as compared with 116,692 tons in February and 119,273 tons in January. The United States had by far the largest output at 29,197 tons.

Day-to-day quotations :—

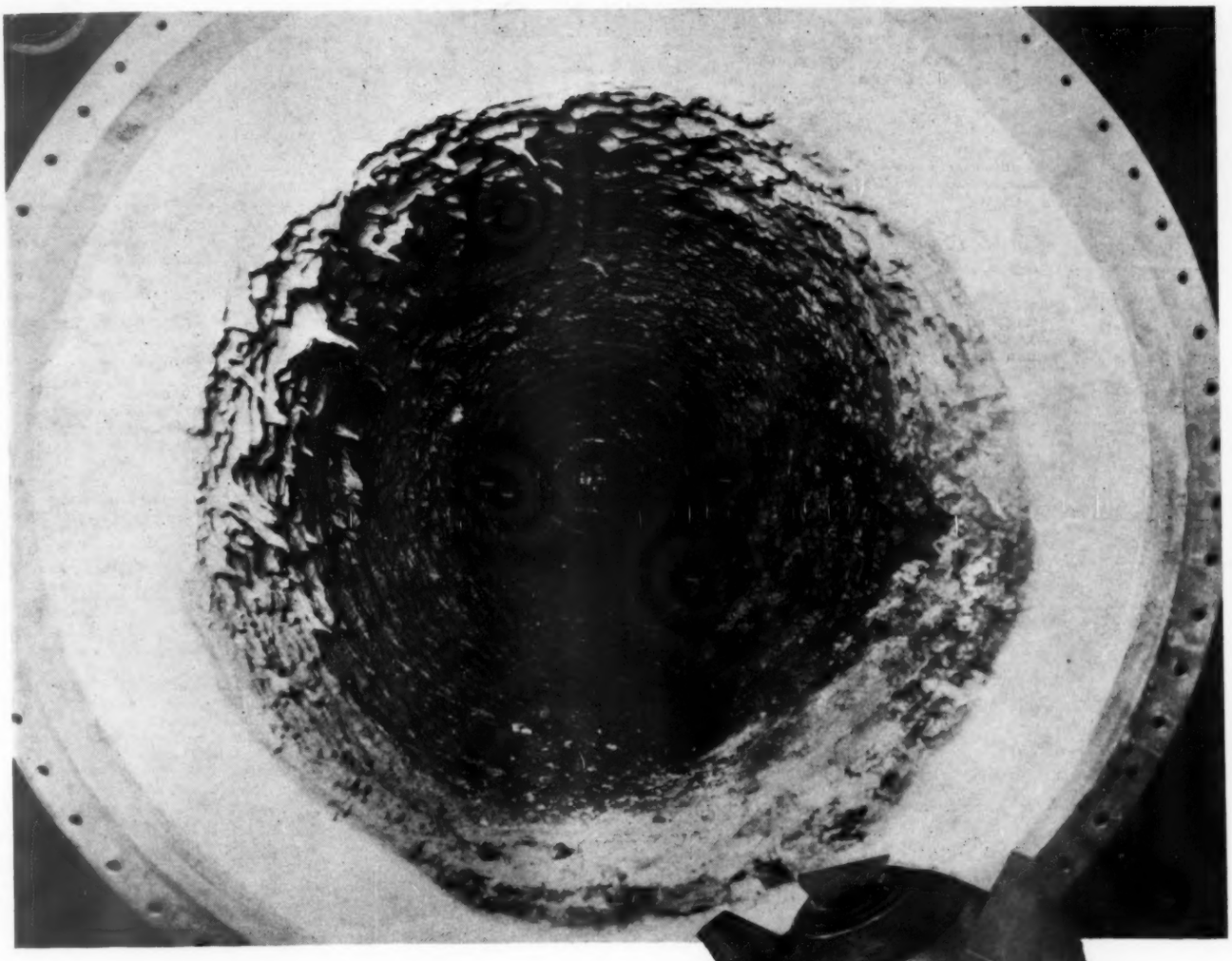
Soft Foreign (Prompt).—Thursday, £15 3s. 9d.; Friday, £15 3s. 9d.; Monday, £15 6s. 3d.; Tuesday, £15 10s.; Wednesday, £15 6s. 3d.

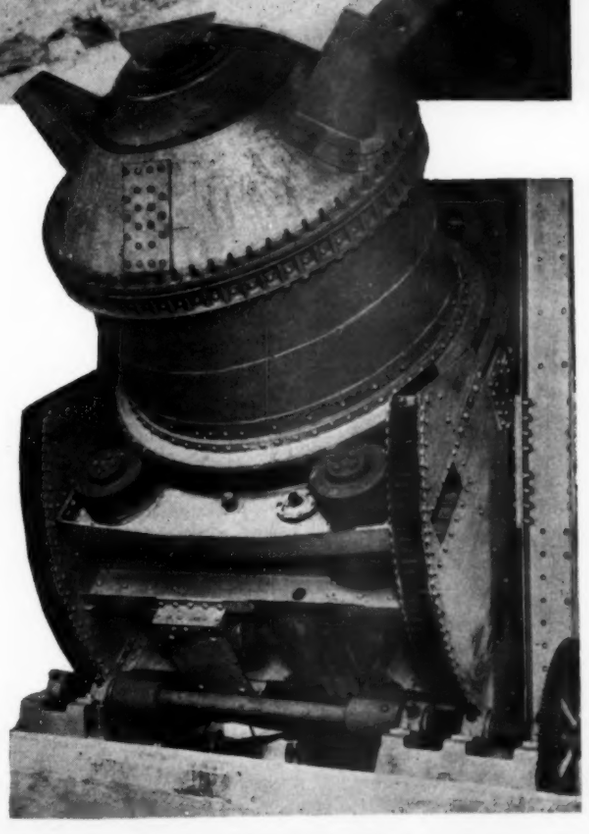
Arsenic Estimation in Iron and Steel

Report No. 111 of the chemical sub-committee of the Verein deutscher Eisenhüttenleute, compiled by A. STADELER, and published in the "Archiv für das Eisenhüttenwesen," reviews the various methods employed for the estimation of arsenic in steel, pig-iron and ores in which the arsenic is dissolved out and then distilled, the element being estimated in the distillate. In steelworks laboratories the most suitable methods for steel and pig-iron employ bromine water or nitric acid as a solvent, and no precautions are necessary to prevent loss of arsenic by volatilisation. In the case of ores, containing arsenic as oxide, treatment with hydrochloric acid or bromine-hydrochloric acid is recommended. In the distillate the arsenic can be best estimated gravimetrically as trisulphide, as ammonium magnesium arsenate and as magnesium pyro-arsenate, or by titration by the iodometric or bromometric methods. All these methods were found to give reliable results. Of other elements which might be present only antimony in high percentages will influence the accuracy of arsenic estimation, as in these cases distillation may be carried out at 110 deg. With certain special elements the solution residues obtained may retain small amounts of arsenic, and these residues must therefore be broken up for the liberation of the arsenic content. This report is useful in presenting a brief but comprehensive survey of current technique of arsenic estimation in iron and steel.

Pickling Stainless Steels

Pickling media for stainless steels, according to an article in "Metal Progress," consists of 10 per cent. sulphuric acid with 2 to 10 per cent. hydrochloric acid, or a mixture of 10 per cent. sulphuric acid with about 10 per cent. of common salt.





930 tons of metal melted—

The above photograph shows the condition of an 04 grade Albino lining in a 5-ton Brackelsberg furnace after 255 heats, which melted 930 tons of metal. You will observe the lining has worn evenly and it is still approximately 8″ in thickness. The 04 grade is specially produced for rotary furnaces, but there are other grades for lining cupolas, converters and ladles.

These photographs are reproduced by courtesy of James Howden and Company (Land), Ltd.

ALBINO

Rotary Furnace Lining Material

Please write for further particulars to the sole manufacturers:—

GENERAL REFRACTORIES LIMITED,

Genefax House, Sheffield 10.

Telephone: Sheffield 31113 (6 *lines*). *Telegrams: "Genefax Sheffield."*

MANUFACTURERS OF HEAT RESISTING AND HEAT INSULATING MATERIALS OF EVERY DESCRIPTION

RAW MATERIALS—PRICE LIST

(Wednesday, June 10, 1936)

COPPER

	£	s.	d.
Standard cash	36	1	3
Three months	36	7	6
Electrolytic	40	7	6
Tough	38	15	0
Best selected	39	5	0
Sheets	68	0	0
India	49	12	6
Wire bars	40	10	0
Ingot bars	40	10	0
H.C. wire rods	44	2	6
Off. av. cash, May	36	14	6⅜
Do., 3 mths., May	37	0	2⅝
Do., Sttlmnt., May	36	14	6⅜
Do., Electro, May	41	0	8½
Do., B.S., May	40	9	2
Do., wire bars, May	41	4	7½
Solid drawn tubes			10½d.
Brazed tubes			10½d.
Wire			6½d.

BRASS

Solid drawn tubes	9½d.
Brazed tubes	11½d.
Rods, drawn	8½d.
Rods, extd. or rlld.	5d.
Sheets to 10 w.g.	8d.
Wire	7½d.
Rolled metal	7½d.
Yellow metal rods	5d.
Do. 4 × 4 Squares	5½d.
Do. 4 × 3 Sheets	5½d.

TIN

	£	s.	d.
Standard cash	183	10	0
Three months	181	10	0
English	183	10	0
Bars	184	15	0
Straits	185	10	0
Australian (nom.)			—
Eastern	186	7	6
Banca	185	10	0
Off. av. cash, May	202	12	1½
Do., 3 mths., May	197	4	4½
Do., Sttlmt., May	202	12	4½

SPELTER

	£	s.	d.
Ordinary	14	2	6
Remelted	13	15	0
Hard	11	0	0
Electro 99.9	16	5	0
English	15	0	0
India	12	10	0
Zinc dust	19	10	0
Zinc ashes	4	5	0
Off. aver., May	14	13	1½
Aver. spot, May	14	10	8½

LEAD

Soft foreign ppt.	15 6 3
Empire	16 5 0
English	17 10 0
Off. average, May	15 11 3½
Average spot, May	15 10 7½

ALUMINIUM

Ingots	£100 to £105
Wire	1/3 to 1/4 lb.
Sheet and foil	1/2 to 1/4 lb.

ZINC SHEETS, &c.

Zinc sheets, English	24 10 0 to 25 0 0
Do., V.M. ex-whse.	24 10 0 to 25 0 0
Rods	26 7 6

ANTIMONY

English	66 10 0 to 67 10 0
Chinese, ex-whse.	55 0 0
Crude, c.i.f.	25 10 0

QUICKSILVER

Quicksilver	11 12 6 to 12 2 6

FERRO-ALLOYS AND STEEL-MAKING METALS

Ferro-silicon—	
25%	8 17 6
45/50%	12 15 0
75%	17 17 6
Ferro-vanadium—	
35/50%	12/8 lb. Va.
Ferro-molybdenum—	
70/75% carbon-free	4/6 lb. Mo.
Ferro-titanium—	
20/25% carbon-free	9d. lb.
Ferro-phosphorus, 20/25%	£21 0 0 to £22 0 0
Ferro-tungsten—	
80/85%	3/- lb.
Tungsten metal powder—	
98/99%	3/3 lb.
Ferro-chrome—	
2/4% car.	33 0 0
4/6% car.	21 10 0
6/8% car.	21 0 0
8/10% car.	21 0 0
Ferro-chrome—	
Max. 2% car.	33 10 0
Max. 1% car.	36 5 0
Max. 0.70% car.	37 5 0
70% carbon-free	9½d. lb.
Nickel—99.5/100%	£200 to £205
"F" nickel shot	£184 0 0
Ferro-cobalt, 98/99%	6/3 to 6/9 lb.
Metallic chromium—	
96/98%	2/5 lb.
Ferro-manganese (net)—	
76/80% loose	£11 5 0 to 11 15 0
76/80% packed	£12 5 0 to 12 15 0
76/80% export	(nom.) £10 5 0
Metallic manganese—	
94/96% carbon-free	1/3 lb.

Per ton unless otherwise stated, basis 2-ton lots.

HIGH-SPEED TOOL STEEL

Finished bars, 14% tungsten	2s. 0d.
Finished bars, 18% tungsten	2s. 9d.

Per lb. net, d/d buyers' works.

Extras—

Rounds and squares, 3 in. and over	4d. lb.
Rounds and squares, under ½ in. to ¼ in.	3d. lb.
Do., under ¼ in. to 1/16 in.	1/- lb.
Flats, ½ in. × ¼ in. to under 1 in. × ⅛ in.	3d. lb.
Do., under ½ in. × ¼ in.	1/- lb.
Bevels of approved sizes and sections	6d. lb.

Bars cut to length, 10% extra.

SCRAP

	£	s.	d.	£	s.	d.
South Wales—						
Heavy steel	3	0	0	to 3	5	0
Mixed iron and steel	3	0	0	to 3	1	6
Heavy cast iron	2	18	0	to 3	0	0
Good machinery	3	2	6	to 3	5	0
Cleveland—						
Heavy steel	2	17	6	to 3	0	0
Steel turnings				2	0	0
Heavy cast iron				3	2	6
Heavy machinery				3	5	0
Midlands—						
Light cast-iron scrap	2	12	6	to 2	15	0
Heavy wrought iron	3	7	6	to 3	10	0
Steel turnings				2	2	6
Scotland—						
Heavy steel				2	17	6
Ordinary cast iron				3	7	6
Engineers' turnings				2	2	6
Cast-iron borings				1	17	6
Wrot-iron piling				3	10	0
Heavy machinery				3	10	0

London—Merchants' buying prices, delivered yard.

Copper (clean)	29 0 0
Brass	19 0 0
Lead (less usual draft)	13 10 0
Tea lead	10 0 0
Zinc	9 0 0
New aluminium cuttings	74 0 0
Braziery copper	26 0 0
Gunmetal	27 0 0
Hollow pewter	150 0 0
Shaped black pewter	105 0 0

PIG-IRON

N.E. Coast (d/d Tees-side area)—

Foundry No. 1	72/6
,, No. 3	70/-
,, No. 4	69/-
Forge No. 4	69/-
Hematite No. 1	80/6
Hematite M/Nos.	80/-

N.W. Coast—

Hem. M/Nos. d/d Glas.	80/6
,, d/d Birm.	92/-
Malleable iron d/d Birm.	125/-

Midlands (d/d Birmingham dist.)—

Staffs No. 4 forge	72/-
,, No. 3 fdry.	75/-
Northants forge	69/6
,, fdry. No. 3	72/6
,, fdry. No. 1	75/6
Derbyshire forge	72/-
,, fdry. No. 3	75/-
,, fdry No. 1	78/-

Scotland—

Foundry, No. 1, f.o.t.	81/6
,, No. 3, f.o.t.	79/-
Cleveland No. 3, Glasgow	73/-
,, ,, Falkirk	70/-
Scottish hem. M/Nos. d/d	80/6

Sheffield (d/d district)—

Derby forge	69/6
,, fdry. No. 3	72/6
Lincs forge	69/6
,, fdry. No. 3	72/6
W.C. hematite	86/-

Lancashire (d/d eq. Man.)—

Derby fdry. No. 3	78/-
Staffs fdry. No. 3	78/-
Northants fdry. No. 3	76/6
Cleveland fdry. No. 3	78/-
Dalzell, No. 3 (special)	102/6 to 105/-
Glengarnock, No. 3	89/-
Clyde, No. 3	89/-
Monkland, No. 3	89/-
Summerlee, No. 3	89/-
Eglinton, No. 3	89/-
Gartsherrie, No. 3	89/-
Shotts, No. 3	89/-

FINISHED IRON AND STEEL

Usual district deliveries for iron; delivered consumer's station for steel.

Iron—	£	s.	d.	£	s.	d.
Bars (cr.)				10	2	6
Nut and bolt iron	8	10	0	to 9	0	0
Hoops			11	0	0	and up.
Marked bars (Staffs) f.o.t.				12	10	0
Gas strip			11	0	0	and up.
Bolts and nuts, ¾ in. × 4 in.			15	15	0	and up.
Steel—						
Plates, ship, etc.	9	7	6	to 9	10	0
Boiler plts.	9	17	6	to 10	0	0
Chequer plts.				11	0	0
Angles				9	0	0
Tees				10	0	0
Joists				9	7	6
Rounds and squares, 3 in. to 5½ in.				10	0	0
Rounds under 3 in. to ¾ in. (Untested)				9	7	0
Flats—8 in. wide and over				9	5	0
,, under 8 in. and over 5 in.				9	10	0
Rails, heavy	8	5	0	to 8	10	0
Fishplates				12	10	0
Hoops (Staffs)				10	2	0
Black sheets, 24g. (4-t. lots)				11	10	0
Galv. cor. shts. (,,)				13	10	0
Galv. flat shts. (,,)				14	0	0
Galv. fencing wire, 8g. plain				15	0	0
Billets, soft			6	2	6	and up.
Billets, hard	7	2	6	to 7	7	6
Sheet bars	5	15	0	to 6	5	0
Tin bars	5	15	0	to 6	5	0

PHOSPHOR BRONZE

	Per lb. basis
Strip	10½d.
Sheet to 10 w.g.	11½d.
Wire	12½d.
Rods	11½d.
Tubes	14d.
Castings	12½d.

Delivery 3 cwt. free.
10% phos. cop. £30 above B.S.
15% phos. cop. £35 above B.S.
Phosphor tin (5%) £30 above price of English ingots.
C. CLIFFORD & SON, LIMITED.

NICKEL SILVER, &c.

	Per lb.
Ingots for raising	7d. to 1/1
Rolled—	
To 9 in. wide	1/1 to 1/7
To 12 in. wide	1/1½ to 1/7½
To 15 in. wide	1/1½ to 1/7½
To 18 in. wide	1/2 to 1/8
To 21 in. wide	1/2½ to 1/8½
To 25 in. wide	1/3 to 1/9
Ingots for spoons and forks	7d. to 1/3½
Ingots rolled to spoon size	10d. to 1/6½
Wire round—	
to 10g.	1/4½ to 1/11½

with extras according to gauge.
Special 5ths quality turning rods in straight lengths, 1/3½ upwards.

AMERICAN IRON AND STEEL

At Pittsburgh unless otherwise stated.

	Dols.
No. 2 foundry, Phila.	21.31
No. 2 foundry, Valley	19.50
No. 2 foundry, Birm.	15.50
Basic, Valley	19.00
Malleable, Valley	19.50
Grey forge, Valley	19.00
Ferro-mang. 80%, seaboard	75.00
O.-h. rails, h'y, at mill	36.37½
Billets	28.00
Sheet bars	28.00
Wire rods	38.00
	Cents.
Iron bars, Chicago	1.80
Steel bars	1.85
Tank plates	1.80
Beams, etc.	1.80
Skelp, grooved steel	1.80
Steel hoops	2.10
Sheets, black, No. 24	2.40
Sheets, galv., No. 24	3.10
Wire nails	2.10
Plain wire	2.40
Barbed wire, galv.	2.60
Tinplates, 100-lb. box	$5.25

COKE (at ovens)

Welsh foundry	25/- to 30/-
,, furnace	20/- to 22/6
Durham foundry	25/- to 26/-
,, furnace	22/6
Scotland, foundry	30/-
,, furnace	25/- to 26/-

TINPLATES

f.o.b. Bristol Channel ports.

I.C. cokes	20×14	per box	18/9
,,	28×20	,,	37/6
,,	20×10	,,	27/-
,,	18¾×14	,,	19/6
C.W.	20×14	,,	15/9 to 16/3
,,	28×20	,,	34/3
,,	20×10	,,	23/-
,,	18¾×14	,,	15/9 to 16/3

SWEDISH CHARCOAL IRON & STEEL

Pig-iron	£6 0 0 to £7 0 0
Bars-hammered, basis	£16 0 0 to £16 10 0
Bars and nail-rods, rolled, basis	£15 15 0 to £16 0 0
Blooms	£10 0 0 to £12 0 0
Keg steel	£30 0 0 to £31 0 0
Faggot steel	£18 0 0 to £23 0 0
Bars and rods dead soft, st'l	£10 0 0 to £12 0 0

All per English ton, f.o.b. Gothenburg.
[Subject to an exchange basis of Kr. 18.16 to £1.]

DAILY FLUCTUATIONS

Standard Copper (cash)

	£	s.	d.		
June 4 ..	36	0	0	dec.	5/-
,, 5 ..	36	0	0	No	change
,, 8 ..	36	5	0	inc.	5/-
,, 9 ..	36	5	0	No	change
,, 10 ..	36	1	3	dec.	3/9

Electrolytic Copper

	£	s.	d.		
June 4 ..	40	0	0	dec.	5/-
,, 5 ..	40	0	0	No	change
,, 8 ..	40	2	6	inc.	2/6
,, 9 ..	40	10	0	,,	7/6
,, 10 ..	40	7	6	dec.	2/6

Standard Tin (cash)

	£	s.	d.		
June 4 ..	183	0	0	dec.	80/-
,, 5 ..	187	5	0	inc.	85/-
,, 8 ..	187	15	0	,,	10/-
,, 9 ..	184	10	0	dec.	65/-
,, 10 ..	183	10	0	,,	20/-

Tin (English ingots)

	£	s.	d.		
June 4 ..	183	0	0	dec.	80/-
,, 5 ..	187	10	0	inc.	90/-
,, 8 ..	187	15	0	,,	5/-
,, 9 ..	184	15	0	dec.	60/-
,, 10 ..	183	10	0	,,	25/-

Spelter (ordinary)

	£	s.	d.		
June 4 ..	14	3	9	inc.	1/3
,, 5 ..	14	2	6	dec.	1/3
,, 8 ..	14	5	0	inc.	2/6
,, 9 ..	14	2	6	dec.	2/6
,, 10 ..	14	2	6	No	change

Spelter (Electro, 99.9 per cent.)

	£	s.	d.		
June 4 ..	16	5	0	dec.	2/6
,, 5 ..	16	5	0	No	change
,, 8 ..	16	5	0	,,	,,
,, 9 ..	16	5	0	,,	,,
,, 10 ..	16	5	0	,,	,,

Lead (soft foreign, prompt)

	£	s.	d.		
June 4 ..	15	3	9	No	change
,, 5 ..	15	3	9	,,	,,
,, 8 ..	15	6	3	inc.	2/6
,, 9 ..	15	10	0	,,	3/9
,, 10 ..	15	6	3	dec.	3/9

Lead (English)

	£	s.	d.		
June 4 ..	17	5	0	No	change
,, 5 ..	17	5	0	,,	,,
,, 8 ..	17	5	0	,,	,,
,, 9 ..	17	10	0	inc.	5/-
,, 10 ..	17	10	0	No	change

AVERAGE MONTHLY PRICES OF DERBYSHIRE NO. 3 FOUNDRY AT MANCHESTER.

Year	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Yearly average
	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.
1900	4 0 0	4 0 0	4 0 0	4 1 6	4 1 0	3 18 0	3 13 6	3 12 6	3 11 0	3 11 0	3 9 6	3 8 0	3 15 5
1901	2 13 6	2 17 0	2 15 0	2 15 0	2 14 0	2 13 9	2 13 6	2 13 6	2 14 6	2 13 0	2 12 6	2 16 6	2 14 3½
1902	2 17 6	2 17 6	2 15 6	2 16 9	2 16 6	2 16 6	2 16 6	2 17 0	2 18 6	2 18 6	2 17 6	2 17 6	2 17 1½
1903	2 17 6	2 17 6	2 17 6	2 17 6	2 17 6	2 17 6	2 17 6	2 17 6	2 17 6	2 17 6	2 17 6	2 17 6	2 17 6
1904	2 17 6	2 17 6	2 17 6	2 17 6	2 17 6	2 17 6	2 17 6	2 17 6	2 17 6	2 17 6	2 17 6	2 17 6	2 17 6
1905	2 13 0	2 13 0	2 11 6	2 12 6	2 12 0	2 12 0	2 12 3	2 12 3	2 14 0	2 16 6	3 0 0	3 0 6	2 14 1
1906	3 2 0	3 5 0	3 3 0	3 0 6	2 17 0	2 18 6	2 18 0	2 16 6	2 19 0	3 0 6	3 1 6	3 7 0	3 0 8½
1907	3 7 0	3 7 0	3 5 0	3 2 0	3 4 0	3 8 0	3 6 0	3 5 0	3 4 0	3 2 6	3 1 0	3 7 0	3 4 2
1908	2 15 0	2 14 6	2 14 6	2 15 6	2 14 0	2 13 0	2 13 0	2 11 6	2 12 6	2 13 0	2 12	2 18 0	2 13 5½
1909	2 13 0	2 12 6	2 11 6	2 12 0	2 12 6	2 12 6	2 12 0	2 12 6	2 14 6	2 15 0	2 14 6	2 12 0	2 13 0½
1910	2 13 9	2 14 0	2 14 0	2 14 4	2 15 0	2 15 0	2 14 9	2 15 0	2 15 0	2 15 0	2 15 0	2 14 0	2 14 7½
1911	2 16 0	2 16 0	2 16 0	2 16 0	2 16 0	2 16 0	2 16 0	2 16 0	2 16 0	2 14 6	2 15 0	2 15 0	2 15 8½
1912	2 17 4½	2 17 6	2 17 6	3 1 1½	3 2 6	3 3 9	3 6 3	3 7 6	3 10 10½	3 12 6	3 13 3½	3 14 6	3 5 4
1913	3 15 7	3 15 0	3 11 10½	3 11 4½	3 10 2½	3 6 10½	3 4 2½	3 2 9	3 1 9	3 1 0	2 19 3	2 17 2½	3 6 5
1914	2 17 2½	2 18 0	2 18 0	2 17 0	2 17 0	2 16 7½	2 16 0	3 2 10	3 1 0	2 19 9½	2 16 11½	2 18 1½	2 18 2
1915	3 1 2	3 3 11	3 5 9	3 18 8½	3 13 7	3 14 1	3 15 0	3 13 3	3 12 0½	3 11 1	3 14 0	4 3 3	3 12 2½
1916	4 4 6½	4 11 6	4 11 6½	4 7 6	4 7 6	4 7 6	4 10 0	4 12 10	4 12 6	4 12 6	4 12 6	4 12 6	4 8 6½
1917	4 12 6	4 12 6	4 12 6	4 12 6	4 12 6	4 12 6	4 12 6	4 12 6	4 12 6	4 12 6	4 12 6	4 12 6	4 12 6
1918	4 12 6	4 12 6	4 12 6	4 12 6	4 12 6	4 12 6	4 12 6	4 12 6	4 12 6	4 12 6	4 12 6	4 12 6	4 12 6
1919	4 12 6	4 12 6	4 12 6	4 12 6	7 2 6	7 5 0	8 8 5	9 0 0	9 0 0	9 0 0	9 0 0	9 0 0	7 3 10
1920	9 13 9	10 0 0	10 5 3	10 15 3	11 10 0	12 2 6	12 5 0	13 1 3	14 7 6	14 5 0	14 5 0	14 5 0	12 12 1½
1921	12 11 8	10 8 9	9 2 6	8 2 0	8 0 0	8 0 0	8 0 0	8 1 8	7 4 0	6 7 6	5 7 6	4 1(10	8 0 2
1922	5 5 0	4 17 6	4 15 0	4 15 0	4 12 6	4 12 6	4 12 6	4 12 6	4 11 3	4 10 0	4 10 0	4 10 0	4 13 7½
1923	4 12 8½	5 0 2	6 2 6	6 8 7½	6 2 5	5 11 9	5 9 1½	5 4 0	5 0 0	5 0 9	5 0 7	5 2 9	5 7 11½
1924	5 3 0	5 3 0	5 3 0	5 3 0	5 2 10	5 1 3	4 17 11	4 15 6	4 13 6	4 10 1½	4 10 0	4 10 3	4 17 9½
1925	4 10 0	4 9 0	4 6 9	4 5 2½	4 3 0	4 0 1½	4 17 1½	3 15 7½	3 14 3½	3 13 4½	3 13 4½	3 13 2½	4 1 9
1926	3 14 9	3 15 3	3 15 6	3 15 3½	3 17 6	4 5 9	4 16 9	*	*	*	*	4 12 6	4 0 1½
1927	4 13 9½	4 13 3	4 11 1½	4 9 4½	4 6 1½	3 19 1½	3 16 1½	3 15 6	3 13 4½	3 13 4½	3 14 0	3 13 6½	4 1 6½
1928	3 13 2½	3 12 3½	3 12 3	3 12 3	3 11 6	3 10 0	3 8 3	3 7 8½	3 7 6	3 7 9½	3 8 3	3 7 6	3 9 10½
1929	3 8 3½	3 10 4½	3 10 10½	3 11 0	3 11 2½	3 12 0	3 12 4½	3 14 6	3 15 1½	3 17 0	3 17 0	3 17 0	3 13 1½
1930	3 17 0	3 17 0	3 17 0	3 17 0	3 17 0	3 17 0	3 15 0	3 12 0	3 12 0	3 12 0	3 10 1½	3 9 6	3 14 4½
1931	3 9 6	3 9 6	3 9 6	3 9 6	3 7 0	3 7 0	3 7 0	3 7 0	3 7 0	3 7 0	3 7 0	3 7 0	3 7 10
1932	3 7 6	3 7 0	3 7 0	3 7 0	3 7 0	3 7 0	3 7 0	3 7 0	3 7 0	3 7 0	3 7 0	3 7 0	3 7 0
1933	3 7 0	3 7 0	3 7 0	3 7 0	3 7 0	3 7 0	3 7 0	3 7 0	3 7 0	3 7 0	3 7 0	3 7 0	3 7 0
1934	3 7 0	3 9 6	3 13 2½	3 14 0	3 14 0	3 14 0	3 14 0	3 14 0	3 14 0	3 14 0	3 14 0	3 14 0	3 12 11½
1935	3 14 0	3 14 0	3 14 0	3 14 0	3 14 0	3 14 0	3 14 0	3 14 0	3 14 0	3 14 0	3 18 0	3 18 0	3 14 8
1936	3 18 0	3 18 0	3 18 0	3 18 0	3 18 0	—	—	—	—	—	—	—	—

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